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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, May 28, 1902.

The 166th meeting was held this date at the house of the American Society of Civil Engineers, 220 West 57th street, and was called to order by President Steinmetz, at 8.15 P. M.

PRESIDENT STEINMETZ:—Gentlemen: While calling to order the 166th meeting of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, I extend a hearty welcome to our guests—the officers of the United States Army and Navy, who honor us not only by their presence, but still more by participating in the work of the evening, to the members of the Society of Marine Engineers and Naval Architects, the members of the American Society of Civil Engineers, the members of the American Institute of Mining Engineers, and the members of the American Society of Mechanical Engineers.

I am happy to be able to state that the INSTITUTE has been presented with a very good portrait of Lord Kelvin who, as you know, was recently our guest. This portrait has been presented by our Committee on Papers, and is now on exhibition in this hall, and will be permanently placed in our rooms.

We will now proceed to the presentation of the papers of the evening. I am happy to say that we have a considerable number of interesting papers,and also expect a very interesting discussion. Therefore, it becomes necessary to abstract the papers, and ten minutes will be given to each paper for that purpose, and then each gentleman who wishes to take part in the discussion will be allotted five minutes. The author of the first paper, Mr. Caryl D. Haskins, is at the present time on the Atlantic, and so cannot be here, and therefore an abstract of his paper will be presented by our Secretary.

The following papers were then read:

" Civilian Coöperation in the development of Electrical Devices for Military Purposes," by Caryl D. Haskins; " Electricity in its Application to Sub-Marine Mines," by Capt. John Stephen Sewell, U. S. A.; " Wireless Telegraphy—United States Navy," by Lieut. A. M. Beecher, U. S. N.; " Electricity in the Navy,"

by Lieut. Harry George, U. S. N.; "The Military Cable System of the Philippines," by Capt. Edgar Russel, Signal Corps, U. S. "The Reasons for the Change of the Navy Standard Voltage from 80 to 125," by Lieut. W. V. N. Powelson, U. S. N.; "Electricity in Permanent Seacoast Defenses," by Maj. George W. Goethals, U. S. A.; "Submarine Cable Testing in the Signal Corps, U. S. A.," by Townsend Wolcott; "Electricity in the Navy," by Walter M. McFarland; "Electricity in the Signal Corps," by Col. Samuel Reber, U. S. A.; "Emergency Engineering for Harbor Defence," by Dr. Louis Bell.

A paper presented at the 166th Meeting of the American Institute of Electrical Engineers, at New York, May 28th, 1902.

CIVILIAN CO-OPERATION IN THE DEVELOPMENT OF ELECTRICAL DEVICES FOR MILITARY PURPOSES.

BY CARYL D. HASKINS.

It has been said that universal peace may be expected when the engines of war become so sure and deadly that no man dare fight. This statement is somewhat crude and doubtless does a grave injustice to the standard of human courage, although perhaps it holds a germ of truth. It is certainly true that the increased deadliness of modern war-engines has been followed by a marked diminution of fatalities in action, and such sanguinary engagements as have occurred in recent years have generally been under conditions involving obsolete equipment.

There are few directions in which electricity is capable of a greater variety of useful applications than in connection with the art of war, and the sole purpose of this brief paper is to make an appeal for closer coöperation between civilian electrical engineers and that other large group of scientists and engineers; namely, officers of the United States Army and Navy.

The AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS has attained a standing and position which entitle it to respect as a national institution; and it seems right and proper that this INSTITUTE should serve, so far as it may, the interests of the United States Government in connection with the improvement and development of our war equipment and methods.

To the officers of the United States Army and Navy, electricity is but one of many forces to be utilized in connection with military appliances and systems. It is therefore not presumptuous to assume that we, who are specialists in this science alone,

may well hope to be of material and lasting assistance in the development or betterment of appliances of this class.

It may perhaps be said that such conditions of coöperation already exist, and it is quite true that in many directions this is the case. Close analysis of the facts, however, will show that such coöperation has been almost wholly confined to those military applications of electricity which are closely paralleled by similar applications in industrial pursuits. There are certain classes of applications, however, which are so purely military in their character as to have received no necessary attention by reason of commercial demands.

I may cite, for example, the general question of range and position finders, or, to make the proposition yet more concrete, the more or less automatic transmission of angles from remote points in a way so positive and reliable as to withstand the rough and arduous conditions of sustained military service. I may also cite the development of the submarine mining system and its control. In connection with this work as well as with range finding systems, etc., I have had some actual experience under service conditions.

Mining systems are probably typical of those military applications of electricity which have been developed exclusively within the service. None of the privileged few who are familiar with the United States system as compared with foreign systems of the same character can fail to appreciate the high genius of Gen. Abbott and his coadjutors, yet I feel that intelligent study by a body of engineers, whose specialty and sole occupation is the study of applied electricity, might result in materially improving the effectiveness of the system and its devices.

I fully realize that the mine defence system of the United States, in common with those of most European countries, has been regarded as necessarily an official secret of a certain limited branch of the service, formerly the Corps of Engineers, now the Artillery Corps. It is, however, well known that such secrecy cannot be very effectively maintained, as is well proved by the fact that there are probably few officers in our service who are not familiar with the systems in use in most of the large European States, and it is probably true that Gen. Abbott's system (now greatly modified) has been well understood in foreign services for some time. Proper official secrecy does not, in short, bar the mining system from such benefits as might result from civilian collaboration.

The rapid and accurate transmission of angles in connection with base line range and position finding from permanently established stations, and the indication of these angles (or even their resultants) at gun positions, mine control stations, or in mortar batteries, present an especial field in connection with which civilian engineers of wide experience might be of material aid, since in this field very numerous alternative methods may be resorted to, each quite different from the other, and each involving the application of ideas based on devices which have been used either in the laboratory, or commercially for other purposes. Such devices might be modified to form the bases of successful systems. The AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS might very properly take up the study of such abstract problems as these, which together with many similar propositions are so academic in their character as to be quite free from the least suspicion of commercialism.

There is another field in which civilian engineers might be of material service to the regular establishment. I refer to the elaboration of plans and the locating of materials for emergency projects. It is quite certain that the civilian engineer is best situated to keep track of materials manufactured for commercial use and to advise application for war purposes. When it becomes necessary to accomplish military ends with makeshift materials, the aid of the civilian engineer in advising with what materials the end can be accomplished, and where these materials can be located, is obviously likely to be helpful. It would seem unwise to wait until the emergency arises to give consideration to this important subject.

It is to be remembered that a war with a first-class power would necessitate the immediate execution of a large mass of electrical work, especially in connection with coastwise defences, communications and mining. A very large number of trained men must necessarily be employed in order to execute such work promptly, and these men must be drawn either from the enlisted forces of the army, or must be raised as volunteer troops after the emergency has arisen. Some comprehensive plan should be elaborated for the finding, organizing and concentrating of a volunteer force of trained electricians officered in part by electrical engineers, and commanded by officers from tha branch of the regular establishment responsible for the work under execution.

A systematic study of this problem would almost certainly

result in recommendations for the establishment of a permanent reserve force, possibly taking the form of a national militia and comparable with the Royal Volunteer Electrical Engineers of Great Britain. It is even conceivable that such an organization might very properly be found to require a permanent cadre, forming a small skeleton attached to the regular establishment, or more probably a small permanent staff of officers.

The volunteer establishment of Great Britain includes 20 companies of submarine miners, which are organized into "Mining Sections," so-called, each section comprising 13 officers and 183 men; and the "Volunteer Electrical Engineers" are organized as a battalion, having 29 officers and 547 men.

I do not wish to be misunderstood as recommending or advocating the organization of any specific force. My sole purpose is to recommend the whole great question as one worthy of attention at the hands of the officers of the regular establishment and of the members of this INSTITUTE.

There are some dozens of military electrical problems which must go on through a long course of elaboration and development in common with all other war methods and appliances, and I therefore respectfully suggest to the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS that it might be highly proper to constitute a committee whose sole purpose should be to coöperate with the various bureaus of the army and navy in connection with the development and betterment of electrical war projects. It is reasonable to anticipate that such a committee would be heartily welcomed by, and highly useful to, the sister services and the Government.

A paper presented at the 160th Meeting of the American Institute of Electrical Engineers, at New York, May 28th, 1902.

ELECTRICITY IN ITS APPLICATION TO SUBMARINE MINES

BY CAPT. JOHN STEPHEN SEWELL, U. S. A.

A system of submarine mines usually involves stationary torpedoes planted under water, anchors for holding them in position, cables for connecting them electrically with the shore, and operating apparatus in a sheltered position on shore. The torpedo itself is usually a metal case, containing a charge of suitable explosive, with necessary detonators, etc. It may, and in shallow water usually does, rest on the bottom, the metal envelope being in this case sufficiently heavy to act as an anchor. In water more than 35 or 40 feet deep, the torpedo is usually buoyant, and is held in place by a separate anchor and mooring rope. Torpedoes may be purely mechanical in their action; in this case, there are usually a number of movable pistons projecting through stuffing boxes at various points, and so arranged that if driven in by the impact of a vessel, they will explode a detonator, which, in turn will explode the torpedo. It will be readily granted that such torpedoes are dangerous to handle, and are not likely to remain long in an efficient condition in sea water. Again, in some rare instances, use may be made of what might be called self-acting electrical torpedoes, in which a battery and circuit-closer, in series with an electrical detonator, are enclosed in the metal case, along with the charge of explosive. The circuit-closer is supposed to act under the impact of a vessel, and the battery does the rest. Some form of dry cell is manifestly the only proper battery for such uses.

In planting self-acting mines, it is necessary to have a safety

device which will maintain an open circuit, in spite of the circuit-closer, until the operations of handling and planting are completed, and those engaged in the work have had time to put a safe distance between themselves and the mine. After this, such a torpedo is dangerous alike to friend and foe, and its removal is an exceedingly delicate operation. For this reason, and also because a thoroughly satisfactory safety device is very hard to find, self-acting mines have a very restricted sphere of usefulness.

By far the greater part of all submarine mines are electrically operated from the shore. This follows directly from a consideration of the conditions to be met in devising a system of mines. It is very desirable for a mine to explode automatically when struck by a hostile vessel; but it is equally desirable for it not to explode if it is struck by a friendly vessel; the defense should also be able to explode the mines at will from the shore, in case a hostile vessel comes near, but seems likely to miss them. All these things are rendered possible by mines electrically operated from the shore.

It is necessary, of course, to proceed with accuracy and precision, in order to attain successful results with such a system. Mines are, primarily, obstructions and not weapons; their principal function is to prevent the enemy from running by the batteries, which experience has demonstrated that he can do, if he has a clear channel. They must be located where, if he tries to remove them, he will be detained under the close fire of the shore guns; otherwise he would remove them and then run by. They must be sufficiently numerous to prevent his opening a channel through them by the sacrifice of any reasonable number of vessels, sent in to receive an explosion and then turn to one side and sink out of the channel. They must be accurately located and planted in regular order, so that there will be no mistake about exploding the proper mine in judgment firing and so that in case of automatic firing, the exploded torpedo may be replaced with the least delay.

It is customary to plant mines in smaller and larger groups; (usually more than one torpedo is attached to a single cable core) and the various cores, as they approach the shore, are gathered into a multiple cable of several cores. Thus, starting with a cable of ten cores, it should be laid by the most direct line from the operating casemate to a convenient point in the rear of the line of mines it is to serve; there, by means

of a large junction-box, it would be connected with ten single-core cables, each leading to one of a line of smaller junction-boxes; at the small junction-boxes, each single conductor branches into perhaps three other single conductor cables, each of the latter going to a torpedo. By this arrangement, when firing is by judgment, which involves some uncertainty as to the actual distance of the hostile vessel from the mines, the defense explodes three charges at once, thus increasing the probability of an effective blow; if, on the other hand, the hostile vessel strikes a torpedo, only that one will explode, and being in contact with its target, it ought to be sufficient.

Coming now to the electrical arrangements, if firing were by judgment alone, nothing would be needed but a circuit from the firing battery through the detonators in the torpedo to earth, with a firing key in the casemate. Even very defective insulation would not interfere with the working of the system, if the firing battery was enduring and sufficiently powerful. It would interfere with the daily tests, however, because of the variations in resistance which would occur even if no leaks or other defects developed in the torpedo itself. If firing is by contact alone, the necessary arrangements are a little more complex.

In order to admit of daily electrical tests—which must include the circuit through the detonators to be of any value—there must be a continuous circuit through the torpedo; it must be of high resistance, so that even if the firing battery is on, it can not fire the mine. There must be a circuit-closer in series with the detonators, and in parallel with the high resistance. When the mine is struck, the circuit-closer acts, and opens up a circuit of lower resistance through the detonators. It is assumed that the detonators are of the type having a continuous bridge of fine wire, surrounded by some fulminating substance, and designed for a relatively large current under moderate e. m. f. This is the most certain and reliable form, and is always easy to obtain. If the firing battery is on, the torpedo should explode when the circuit-closer acts.

It is desirable, however, to know whether a torpedo is struck, or whether its circuit-closer acts from any other cause, even if the mine is not to be fired. Moreover, it is objectionable to keep the cables under such high voltage as is necessary in

a firing battery. It therefore becomes desirable to have another battery of very constant e. m. f. always on the circuit. Its e. m. f. and all the resistances in circuit should be so proportioned that normally a tiny current is always flowing; but when a circuit-closer acts, this current should increase to such a point that it will drop a signal, showing to which triple group the torpedo belongs, and also close the circuit of the firing battery through the corresponding cable core. In case the torpedo is fired, the explosion may cause the circuit-closers of neighboring mines to act, and thus the whole system might go up, seriatim. To prevent this, some device is needed which will allow the firing current to flow long enough to explode certainly the mine that is struck, but which will break it immediately thereafter, and keep it broken long enough for neighboring mines to right themselves. It should be remarked here that if ground mines are used for automatic firing, the circuit-closer must be carried in a buoy, similar in form to a buoyant torpedo, anchored to the ground mine, and having an electrical connection with it; so that, with ground mines, the requirements are the same as with buoyant mines.

It will readily be seen that to accomplish all the above objects a more or less complicated set of apparatus is required. It is a good plan so to arrange the signal drops that when they fall they will close a bell circuit, thus causing a bell to ring continuously until the signal is raised; it is also well for the device which cuts off the firing battery after an explosion to ring a bell as long as the firing circuit is open; this gives reasonable assurance that a mine has exploded, even if in the noise of a battle the explosion itself is not heard; pilot lights would do as well as a bell. It is also well to have a very feeble battery for testing purposes only; thus it will be already seen that there may be as many as five separate circuits to provide for in the operating casemate. In addition there may be one more; if a torpedo is struck and fired, the end of the cable leading to it will form an earth which, if not cut out, might be sufficiently good to keep throwing the firing battery on; it would so alter the resistances as to interfere seriously with the proper working of the system, at any rate. At the triple junction-box, a fuse could be inserted, able to carry the firing current, but susceptible of being blown by a more powerful one to be applied as soon as the other mines of the group have righted themselves. If now we assume that a small engine and dynamo are used

in connection with storage batteries to supply current to the various circuits, it will readily be seen that the switchboard problem in the casemate is not a simple one.

If, in addition to automatic firing, it is desired to use judgment firing, we must be able to switch out the high resistance in the mine, or else have this resistance in the form of the primary of an induction coil, with additional detonators in its secondary circuit; in this case, an intermittent or alternating current of high potential and small volume flowing in the primary would induce a firing current in the secondary. A whole triple group would then be fired, and the corresponding core of the multiple cable would be detached from the operating apparatus altogether, until such time as the mines could be replaced.

In purely automatic firing, the high resistance might be omitted altogether, but then a break in the cable core would give the same indication as a mine in normal condition; and the torpedo itself might be filled with water and sunk to the bottom without the fact being discovered.

The daily tests consist in measuring the resistances of the various circuits, and testing all movable parts in the operating casemate. Damage to the system always affects these tests and the expert electrician in charge must learn to infer from his tests what is the probable nature of the damage.

It will readily be seen that except for purely judgment firing, the insulation resistance of cables and joints must be very high, and must remain so. Details of apparatus actually in use have been omitted in this paper, because they are classed as confidential; but enough has been said to show to an electrical engineer that submarine mining presents some problems that demand serious attention. Not the least of these is the problem of junction-boxes which will allow of rapid jointing work of a quality sufficiently good to withstand submersion in sea water for months at a time. Another serious problem is the cable itself. It takes time to make it. If it is kept in store, either wet or dry, the insulation becomes brittle and when the cable is unwound from the reels, in laying, the insulation cracks. Hitherto, the cable used for this purpose has been insulated, taped, and armored. While the work has been of a high grade, it seems to the writer that we will have to come to the use of cable having a lead covering outside of the insulation and steel wire armor outside of the lead. Then, as long

as the lead is intact, cracks in the insulation will be of no consequence. But this form of cable again, will be heavier, harder to handle, more difficult to splice, and considerably more expensive than the armored cable without the lead.

Even after the details of a system of mines are satisfactorily worked out, the planting is a very serious matter, and always will be, unless we discover some way of controlling and firing the mines by induction, without electrical connections from the shore, thus eliminating the cable. Possibly the development of wireless telegraphy may ultimately make this possible, but it is not yet in sight.

A paper presented at the 166th Meeting of the American Institute of Electrical Engineers, at New York, May 28th, 1902.

WIRELESS TELEGRAPHY—UNITED STATES NAVY.

BY LIEUT. A. M. BEECHER, U. S. N.

The navy is on the eve of adopting a new system of signaling, commonly known as wireless telegraphy. We are all so familiar with the ordinary use of telegraphy between stations connected by conducting wires or cables, that the idea of doing away with these seems very strange at first. However, we have long known how to transmit signals from one point to another in a conventional language without a connecting wire between them. Thus visual signals, by means of flags, semaphores, or heliographs, by day, and by searchlights, lanterns, or rockets, by night, have long been used. Sound signals using either steam whistle or gunfire are not uncommon during either daylight or darkness, especially in thick or foggy weather. The only difference is that while with visual signals, light waves or vibrations are utilized, and in sound signals, sound vibrations, in wireless telegraphy, electric vibrations are put into requisition. In order to understand the mode of generation, propagation and reception of electric, or Hertzian waves, we can reason by analogy, and to that end it may be well to recall some well-known facts. A sound is the effect on the ear of a certain vibratory movement in the air, and we can distinguish sounds of different pitch according to their rate of vibration. When a sound is produced at any point it is transmitted to the whole elastic medium surrounding it, and is stopped or deadened only by soft bodies. Sound vibrations may be detected by the ear or by placing in the path of the waves a body whose period of vibration is exactly the same as that of the source; thus a fiddle string will be caused to vibrate by sound waves given out by any instrument tuned to the same pitch, or a singer with a powerful voice, by

singing loudly near a wine glass a note corresponding to its vibrating note, will cause the glass to vibrate and this vibration may be so violent as to shiver the glass.

Light, like sound, is propagated by waves. The difference is that the medium (ether) which vibrates is not the same. The periods of vibration are considerably shorter and the velocity of propagation enormously greater. Electric waves are also propagated in the ether and are very closely associated with light waves. Hertz made a masterly study of these electric waves and by his remarkable experiments has shown that they are propagated through all non-conducting media and have most of the properties of light. They are reflected on conducting surfaces, are refracted in insulating bodies, and can be polarized. They travel at the same velocity as light, about 186,000 miles per second. It is seen, therefore, that there is a very close analogy between electric and light waves.

There are, however, certain properties of electric waves which are very different from those of light. Thus it is found that they are propagated not alone in straight lines, but that they follow along the surface of conductors. They should not, however, be confounded with the other form of electric waves with which we are more familiar. I refer to electric currents. This property of these waves, by which they follow along the surface of a conductor, explains many facts which have been noted in connection with wireless telegraphy. Thus it has been found that communication over salt water is much easier than over fresh water, and that signals may be sent over certain sections of land more easily than over others, or even than over fresh water. It is particularly difficult to get good wireless communication over sandy ground. In each case the ease of communication depends upon the conductivity of the intervening surface stratum, whether it be land or water. This peculiarity of Hertzian waves also accounts for the fact that the curvature of the earth does not interfere with their propagation, so long as the intervening surface stratum forms a conducting medium. These considerations tend to limit the field of wireless telegraphy to the ocean, and it is particularly fortunate that this happens also to be the place where wire communication is most difficult, or even impossible, in such cases as between ships.

Before proceeding to a brief description of the apparatus employed in wireless telegraphy, it should be pointed out how these Hertzian or electric waves are produced, as they are ap-

parently so different from the other variety of electric vibrations, the so-called electric currents with which we are familiar in conducting bodies. An electric current effects a comparatively slow equalization of potential between different portions of a continuous conducting circuit. On the other hand Hertzian waves are generated by an electric spark or an electric discharge and are propagated through space without the aid of a closed circuit. It was shown by Prof. Oliver Lodge in 1876, and again by Dr. Hertz in 1888, that such an electric discharge was not, as was long believed, a mere instantaneous leveling up of the difference of potential between the two electrified bodies, but rather that it took the form of a series of surging waves, inconceivably rapid, oscillating until balance was restored. Moreover, it was shown that these surging waves were capable of setting up similar waves in conducting bodies in their vicinity, provided these bodies were of such electrical capacity as to be able to vibrate electrically at the same rate as the body which emitted them. Such, then, are the waves with which we must deal in wireless telegraphy. From the fact that sparks are always necessary at the sending station, this form of signaling is sometimes called spark telegraphy. Hertz, who did more than any other man to elucidate the properties of these waves, cannot be considered the inventor of wireless telegraphy. Indeed it is difficult to ascribe the discovery to any one man, as, in its present form, so many inventors have contributed to the final result. The sending apparatus is very similar in most of the systems so far produced. It consists essentially of an ordinary Ruhmkorff coil for generating sparks. Specially designed apparatus is generally used for making and breaking the primary circuit. A battery of cells is sometimes used in connection with accumulators or storage batteries for supplying power, but when available and where greater distances of transmission are desirable, a dynamo, either with or without accumulators, is commonly employed to excite the primary of the coil. In its simplest form the battery or dynamo is placed in the circuit with the primary winding, in which also the sending key (ordinary make and break) is inserted. One pole of the secondary winding is then grounded, while the other is electrically connected to the aerial wire. These connections are shown in Fig. 1. These simple connections at the sending station are not now commonly used, but are somewhat complicated by employing an ordinary transformer and a condenser, a battery of Leyden

jars, in addition to the apparatus first used These are used in order to syntonize the apparatus. Fig. 2 shows one arrangement of connections when using the transformer and condenser.

Different arrangements have been adopted by inventors for

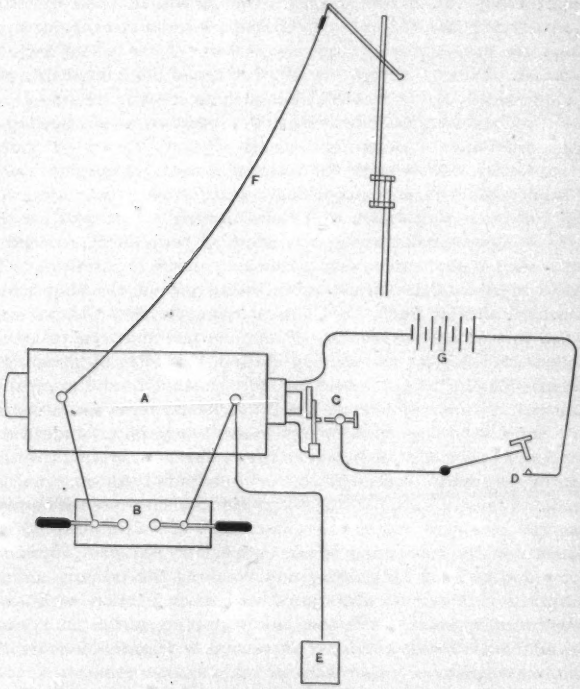


FIG. 1.—Sketch of Sending Connections. (Non-syntonic.)

A.—Induction Coil. B.—Spark Gap. C.—Circuit Breaker. D.—Sending Key. E.—Earth. F.—Aerial Wire. G.—Battery or Dynamo.

varying the inductance and capacity, but no attempt will be made in this short paper to indicate these. The difficulty in obtaining thoroughly satisfactory results in so-called syntonized apparatus will be pointed out later when considering the receiving apparatus.

Various forms and arrangements have been used for the aerial. In most cases on board ship a single wire is used, carried by a sprit or gaff from the masthead. This wire, sometimes naked and sometimes with insulating covering, must be very carefully insulated with hard-rubber or other efficient insulators at the masthead and at all other points where it might come in contact with metal portions of the ship. In some cases two or more wires are used, separated from each other by insulating spreaders, but joined electrically to a single wire at the bottom before reaching the instruments. Wires arranged cylindrically have likewise been tried and metal cylinders have replaced the wires in certain cases. These various arrangements all serve the same purpose, of radiating the electric or Hertzian waves when sending, or of receiving them when the proper connections are made with the receiving apparatus. It should be noted that a station cannot send and receive at the same time. There is greater divergence in the apparatus employed by different inventors for receiving than for sending wireless telegraphic signals. Still nearly all are following the same general lines.

Receiving apparatus may be classed under two general heads. First—those in which a coherer is used with a relay and Morse recording apparatus, and Second—those in which a loose contact or microphone is employed with a telephone receiver. In the latter case no relay is employed and there is no recording apparatus, the message being received by telephone as a series of short or long buzzes, corresponding to the dots and dashes of the Morse code. We will discuss briefly each of these different kinds of receivers, and, as the coherer in the one and the loose contact or microphone in the other are the essential features of each, they will be briefly considered.

The coherer was invented by Prof. Branly in 1890, and without it none of the present wireless telegraphic apparatus using a Morse recorder could have been made. It consists of two cylindrical metal plugs, usually made of silver, placed in a glass tube, with a certain short space between them partially filled with metal filings. Branly made the remarkable discovery that these metal filings ordinarily offer a high resistance to the passage of an electric current, but that under the influence of an electric spark, the resistance is enormously reduced, and the coherer then becomes a conductor and remains so for a considerable time, or until mechanically de-cohered by being shaken or lightly tapped. The spark seems to cause the filings to arrange

themselves end on, forming metallic chains between the electrodes.

This effect of a spark is felt at a great distance, indeed it is impossible to tell the maximum distance at which it will be effective, but it is safe to say that its influence will reach to a distance of 100 or 200 miles in well-constructed apparatus. A coherer enclosed in a metal box is not influenced by a spark, even if produced nearby. If, however, wires connecting up with the elec-

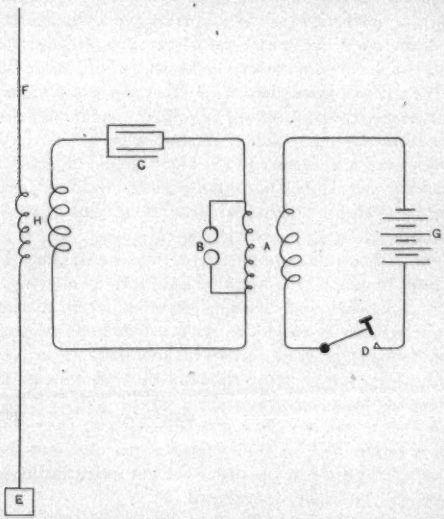


FIG. 2.—Arrangement of Sending Connections. (Syntonic.)
A.—Induction Coil. B—Spark Gap. C.—Condenser D.—Sending Key.
E.—Earth. F.—Aerial Wire. G.—Battery or Dynamo. H—Transformer.

trodes are led out of the enclosing box, the coherer is again affected. This principle of screening the coherer is employed to keep it from being influenced by the sparks produced by the transmitting apparatus at the same station. The coherer is placed in a local circuit with a relay and single cell of low voltage. Under normal conditions the very high resistance of the coherer prevents current from passing, but under the influence of an electric spark, the resistance is broken down and the pass-

ing current actuates the relay. In the derived circuit is an ordinary Morse recording apparatus, and also an ordinary electric hammer which is arranged to tap the coherer gently and thus restore its high resistance by mechanically shaking up the filings between the electrodes. It was pointed out that an electric spark was not a single discharge, but rather a series of inconceivably rapid oscillations backward and forward between the terminal points until balance was restored. The periodicity and length of the waves thus sent out depend upon the capacity and inductance of the conductors discharged. By varying these it has been sought to make certain transmitters affect only certain receivers, or in other words, to syntonize the transmitting and receiving apparatus so as to make selective signaling possible. This has in practice been successful to only a very limited extent. In fact, it may be said that about the only result so far accomplished has been to increase the range of signaling; receivers whether in or out of tune being affected at shorter ranges. The difficulty seems to be due to the very high resistance of the receiving circuit. It takes so much energy to break down the resistance in a coherer, that the oscillations are damped or deadened after one beat. We may liken it to a pendulum swinging in molasses, the resistance of which will practically bring it to rest after a single swing. If this reasoning is correct, we may not expect thoroughly satisfactory results in so-called syntonized apparatus using a coherer receiver.

We will now briefly consider the other form of receiving apparatus using a loose contact in place of a coherer and a telephone in place of the relay and Morse recorder. There is a marked difference between these two methods of receiving. A coherer being influenced only by electric potential must be placed at a potential loop, preferably at the top of the aerial receiving wire, while the microphone, or loose contact, should be placed near the earthing point of the aerial wire where there would be a loop or maximum of current oscillations. It is difficult to understand this difference, unless we remember that in the latter case using a loose contact, we also employ a telephone which is an extremely delicate instrument for detecting variations in current strength. A coherer might be used in place of a loose contact with a telephone receiver, but it is found in practice to be not nearly so sensitive.

The action of the loose contact seems to be that under the influence of the spark the resistance of the circuit is changed

without actually cohering the points and thus no decohering mechanism is necessary. This variation in the resistance causes an audible signal to be given out by the telephone. The signals consist of a succession of short or long buzzes, or musical tones, corresponding to the interruptions of the primary of the induction coil at the sending station.

In practice various forms have been employed for these loose contacts, such as two spheres, a sphere on a plate, a point on a plate, two or three points on a plate, or a kind of gridiron arrangement of bars crossing at right angles. In each case the principle is the same; that is, a change of resistance between the points of contact under the influence of the electric spark. A local circuit with telephone receiver is always used in connection with this loose contact or microphone, and the signal is received by telephone as a succession of short and long buzzes corresponding to the dots and dashes of the Morse code. It has been proposed by some inventors to effect a mechanical tuning in addition to the electrical tuning when using a telephone receiver by making the diaphragm of the telephone respond only to a certain velocity of the circuit-breaker in the primary of the induction coil at the sending station. Prof. Fessenden, working under the direction of the United States Weather Bureau, has lately exhibited an apparatus using a telephone receiver, but employing an entirely different apparatus for varying the current strength and thus producing audible signals. Unfortunately I am not at liberty to explain his devices, but I believe that in some respects his apparatus is more reliable than that of other inventors. It was pointed out above, when speaking of coherer receiving apparatus, that the difficulty so far experienced in successfully tuning different sets seemed to be due in a certain measure to the high resistance of the coherer circuit and the amount of energy necessary to break down this resistance. We might expect to be more successful in tuning apparatus in which a microphone and telephone receiver are used, as the resistance in the local receiving circuit in the latter case is not nearly as high as when using a coherer. Recent reports seem to show that this is the case, and that selective signaling can be carried on between several different sets of transmitters and receivers in the same vicinity without interfering with one another. The great defect of the telephonic receiving apparatus has been the need of an efficient calling-up signal, and it is possible that the wireless apparatus of the future will take the form of a combina-

tion of the two kinds of receiving apparatus, in which a coherer will be used in connection with a relay and electric bell for calling up, and a telephone receiver switched in for receiving the message. Such an arrangement would have many advantages, the most important being the greatly increased speed of sending and receiving possible when using a telephone receiver, and at the same time the present unreliability of the coherer would not be so disadvantageous when its use was confined solely to calling up, or rather to detecting a call from another station.

There is another kind of receiving apparatus sometimes used, differing from either of those mentioned before. In that, an anti-coherer is employed in place of the coherer, and this is used both with a relay and Morse recording apparatus and also with a telephone receiver. The action of the anti-coherer is exactly opposite to that of a coherer. Under normal conditions a certain resistance is maintained in the anti-coherer circuit. Under the influence of an electric spark this resistance is increased. The silvering on an ordinary glass mirror, if scratched with a sharp point so as to separate the silvering into two portions, becomes an anti-coherer when these separate portions are connected up electrically in a receiving circuit. Under the influence of an electric spark the resistance to the flow of current across the scratch is increased. Other forms of anti-coherers have been invented. It is thought, however, that none of these has proved as reliable in practice as the coherer or loose contact.

Having thus briefly described in a general way the apparatus employed by different makers and inventors, I would like to point out what has actually been done, and what we expect to do, in the way of actually installing wireless telegraphic apparatus on board naval vessels. In the first place the masts of all ships are now being altered and prepared for the installation of wireless apparatus. This is a work of some magnitude as it necessitates increasing the height of the masts from about 120 feet to about 135 feet. The old height of 120 feet had been fixed as the maximum which could safely pass under Brooklyn Bridge. Of course, in the new arrangement, provision is made for housing the mast for this purpose. The upper portion of the mast, at least 50 feet, is of wood and is stayed with hemp rigging, or, in the case of rigging coming lower down than 15 feet from the masthead, it may be of wire set up with hemp lanyards.

Wireless telegraphic masts have also been erected at the Navy Yard, Washington; at the Naval Academy, Annapolis, and are

being erected at the Navy Yard, New York, the Naval Station, Key West, and at Dry Tortugas. It is proposed to test thoroughly all the various kinds of wireless telegraphic instruments at these several shore stations and on board naval vessels, and after determining upon the system best adapted to varying service conditions, it will be adopted as the standard for the service and all naval vessels will be supplied with it.

It is needless to point out how greatly this new system of signaling will facilitate fleet maneuvers and operations, particularly in the way of supplying and communicating information gained by scouts, and the greatly enlarged field of action in which a single commander may, at all times, be promptly supplied with all important information, and may at the same time control and distribute his fleet to the best advantage.

A paper presented at the 160th Meeting of the American Institute of Electrical Engineers, at New York, May 28th, 1902.

ELECTRICITY IN THE NAVY.

BY LIEUT. HARRY GEORGE, U. S. NAVY.

The recent progress in the application of electricity to naval purposes has been very marked. It would be well to sketch the development of this form of energy in the naval service and its numerous applications both for lighting and power in recent years, and to conclude a brief historical summary by a comparison of our own vessels with those of foreign navies.

The advantages of electricity on board ship from a military point of view have long been recognized, particularly with regard to the incandescent lamp and the electric projector. In the old installations these features were alone considered, and anyone having experience with electric lights on shipboard will testify to their advantages over the old method of illumination; less liability to fire, reduction in radiant heat, greater illuminating power, no smoke or disagreeable odors, and no vitiation of the atmosphere by the consumption of oxygen, all these advantages adding greatly to the efficiency of the ship and the health, comfort and cheerfulness of the personnel.

The U. S. S. *Trenton* was the first man-of-war in the world to be lighted by the incandescent lamp. This installation was made in 1883, and consisted of a single dynamo, supplying current to 238 lamps, with a total candle power of 3090. The installation of the electrical apparatus of the ship was superintended by Lieut.-Commander R. B. Bradford, now Rear Admiral and Chief of the Bureau of Equipment. This officer became executive of the vessel, and has been closely identified, both officially and from personal interest, with the development of electricity in our navy.

The lighting of the *Trenton* proved a success and was in operation for a full three years' cruise, and confirmed the opinion that no modern vessel is complete without a plant for lighting by electricity.

The proved efficiency of the *Trenton's* installation and the valuable experience gained in that vessel led to the application of electricity for lighting other vessels. The ships authorized by Act of Congress in August, 1882, viz., the *Dolphin*, *Atlanta*, *Boston* and *Chicago*, were so equipped, and since that time an electric plant has been looked upon as an essential feature of all vessels of war, and the scope has been extended to include both lighting and the electric drive of numerous auxiliaries which have hitherto been controlled by steam or hydraulic power.

The early ships were provided with one generator, hence in case of breakdown it was necessary to have recourse to oil lamps. The specifications for the next vessels, authorized by Act of Congress in 1885 and 1886, called for two complete plants, each an exact duplicate of the other. This was not decided upon without some opposition. It was proposed originally to install two generators, one of large capacity to supply the night load and a smaller one to furnish current for lamps required during the day. This idea was finally abandoned on account of the possible overpowering of the smaller dynamo by the large one, unless carefully watched, the decreased relative economy of small generators, and the diminished number of spare parts necessary in a duplicate installation.

The standard voltage on board our ships until recently was 80 volts, a standard adopted by several foreign services. Recently the standard has been changed from 80 to 125 volts, and the latter voltage is to be used in the majority of the vessels now under construction and in all future installations. The considerations that led to this change and the advantages ac cruing therefrom are discussed by an officer who presents a paper on the subject at this meeting, and who served as a mem ber of a special board ordered by the Navy Department to decide on the voltage best adapted to naval purposes

Under the old regulations the electrical illumination of a ship came under the cognizance of the Bureau of Navigation, and the searchlights with their accessories under the Bureau of Ordnance, and separate generators were installed for these purposes. At present, all generators are installed by the Bureau of Equipment, which also includes under its cognizance search-

lights, wiring, conduit fixtures, switchboard, dynamo-room fittings, wiring appliances and supplies, and accessories and instruments necessary for the care, maintenance and preservation of the electric plant.

Each bureau installing electrically operated machinery has cognizance of and installs the motors and controlling apparatus for this purpose. It is thus seen that the electrical installation of a ship falls under the control and supervision of the Bureau of Equipment, Bureau of Construction and Repair, Bureau of Ordnance and, to a more limited extent, the Bureau of Steam Engineering.

The advantage of the electric drive for auxiliaries appears to be as evident as the superiority of the incandescent lamp over the oil lamp or candle for illumination. The confidence engendered by the use of electricity in the early ships and the rapid commercial development of motors and their controlling apparatus gave an impetus to the use of the electric drive on shipboard, and at the present time we find motors installed for ventilating blowers, ammunition hoists, turret-turning, elevating and loading of guns, workshop machinery, and the handling of boats and heavy weights. Steam or hydraulic power for auxiliarydriving has been relegated to the background, and the day is not far distant when auxiliary machinery of all descriptions will be operated by electricity.

The motor is peculiarly well adapted to naval use. Compared with steam, the cutting of bulkheads and decks is reduced to a minimum, and hence the water-tight system is more efficient, the circuits may be better protected than in the case of steam pipes and offer a smaller target. The cutting of a circuit by shot involves no danger to the personnel, and to surrounding appliances, and in case of accidents is more readily repaired. There is no leak from joints and valves, and no appreciable loss of energy in elbows and turns, no loss by condensation, and much less by radiation. The motors are also more efficient and there is relatively less loss in small motors than in small steam engines; they are less likely to get out of order; there are no reciprocating parts to adjust and their operation is simpler and requires less supervision.

The advance of electricity for naval purposes may be illustrated by a comparison between the electric plant of the *Indiana* one of our first battleships, completed and commissioned in 1895, and that of the *Kearsarge*, one of our latest battleships,

commissioned in 1900. The displacement of the *Indiana* is 10,200 tons, and she is equipped with three 24-kilowatt, 80-volt generators for supplying current to 500 incandescent lamps, four 60-centimetre searchlights, two 2 h.p. ventilating motors for dynamo-room, four ¼ h.p. portable ventilating blowers, with winches and ammunition hoists, covering about 36 h.p., or a total output of 67 kilowatts, about 7 watts per ton of displacement.

The *Kearsarge*, with a displacement of 11,525 tons, is provided with seven 50-kilowatt generators, compound-wound, direct-connected, 80 volts, to supply the following demand for lighting and power:

	WATTS.
700 incandescent lamps	48,000
4 30″ searchlights	6,000
Ventilating motors and portable fans	98,000
Ammunition hoists and whips	115,138
Training, elevating and rammer motors	171,580
Boat-cranes and winches	216,350

a total of 655,240 watts, or approximately 57 watts per ton of displacement.

In this connection the practice abroad is shown in representative vessels of the German, Russian and French navies:

GERMANY.

Furst Bismarck:—Battleship, 10,650 tons displacement, with an electric generating plant of 325 kilowatts output, supplying current to 900 incandescent lamps, 44 motors for ventilation, drying-room, ammunition hoists, gun-training gear, coal winches, refrigerating plant, and searchlights.

Kaiser Frederick III.—Armored cruiser, 11,130 tons displacement. Five generators, with output of 324 kilowatts supplying power in watts as follows: Incandescent lighting, 38,260; searchlights, 55,500; ventilation, 28,340; ammunition hoists, 78,440; gun-training gear, 8,880; coal winches, 7,400; refrigerating plant, 4,500.

RUSSIA.

Retvizan:—Battleship built at Cramp's Shipyard, Philadelphia, Pa. Electric installation, three 132-kw., four 66-k.w. and one 60-k.w. generators with a maximum output of 588 kilowatts. These generators supply current to 1167 incandescent lamps six 30″ projectors, and the following auxiliaries:

4 turret-turningmotors,
4 elevating motors.
4 rammer motors.

4 turret ammunition hoists.
12 60″ blowers for forced draft system.
18 motors for hull ventilation.
6 pump motors.
2 boat-crane motors.
1 capstan motor.
8 ash hoist motors.
1 steering motor.
30 ammunition hoist motors for battery.
2 submerged torpedo motors.
1 workshop motor.
1 torpedo lathe motor.
1 bread-mixing motor.
1 laundry motor.

Also a number of portable fans, helm indicators, and other electrical signaling devices.

FRANCE.

Jena:—Battleship. Displacement 12,052 tons. Two generators of 98.4 k.w. capacity, and two of 49.2 k.w. capacity. Total output, 295.6 kilowatts.

The general subject of electrical installations will be taken up under the following headings: Dynamo-rooms and Accessories, Generators, Circuits, Wire and Wiring Appliances, Motors, Interior and Exterior Signaling or Communicating Systems, Searchlights and Incandescent Lamps.

DYNAMO-ROOMS.

For security in time of action, the dynamo room is located below the water line underneath the protective or armored deck, in close proximity to the source of steam supply. The chief considerations are protection, ventilation, accessibility, and a central position for the economical distribution of electrical energy. The compartment assigned to the dynamos may be a single one between transverse water-tight bulkheads, or may consist of two or more such compartments in the larger vessels. Fig. 1 shows the general arrangement of dynamos in the U. S. S. *Alabama*, in four dynamo-rooms between two transverse water-tight bulkheads. This plate also shows the arrangement of steam and exhaust piping. The dynamo room is generally provided with its own ventilating system and contains the switchboards, searchlight panels, rheostats, tool boards, work benches, oil and waste tanks, and the accessories necessary for the efficient operation of the plant.

The generators are mounted on light steel foundations, consisting of plating, angle and channel bars, with a yellow pine or

teak backing, and are further braced by stanchions tying the flat or platform to the protective deck above, and stanchions bracing to the deck below, with such other stiffening bars and braces as may be found necessary to reduce vibration to a minimum.

Heretofore the dynamos have been located in the same portion of the vessel. the dynamo-rooms forming subdivisions of one general compartment between transverse water-tight bulkheads. The rapid development of the electric drive and its application to ammunition hoists and gun operation has made the

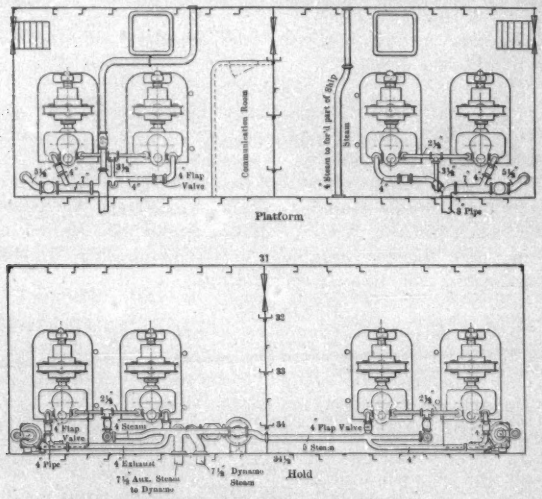


FIG. 1.—Arrangement of Steam and Exhaust Pipes in Dynamo Room, U. S. Battle Ship *Alabama*.

question of dynamo-rooms and their location one of the most important in ship design. In the proposed 16,000-ton battleships recently authorized by Congress, it is proposed to install the generators in two separate compartments, the dynamo-rooms to be entirely independent of each other electrically, and to be situated at opposite ends of the vessel. Each dynamo-room is to be supplied with four 100-k.w. sets, which will supply the output necessary to handle the battle load, for lighting and all auxiliaries. All forward circuits will be supplied by adistri-

buting board located near the forward dynamo-room but separated from it; all after circuits from the after distribution board, similarly situated. By suitable transfer switches both the distributing boards may be electrically connected and the entire load thrown into either dynamo-room at will. This will increase the military efficiency of the installation, as in case of accident rendering either dynamo-room uninhabitable, the battle load may be thrown on the remaining room.

Engines and Dynamos.

The generating set of the *Trenton* above referred to, consisted of a horizontal Armington and Sims 9½″ by 12″ simple engine, belted to an Edison under-type dynamo, and although heavy and cumbersome as compared with generators of the present type, it gave good and efficient service. The dynamo was shunt wound, 100 volts, 120 amperes and rated as a 150, 16 c.p. light machine. Belted sets were installed on several vessels up to the latter part of the 80's, when direct-connected sets first made their appearance.

The Edison under-type dynamos were found to produce an effect on the ship's compasses, owing to magnetic leakage and large stray field, a defect which has been entirely obviated by the use of multipolar or ironclad types of generators.

The early direct-connected sets had horizontal engines and by ingnieous design were fairly compact and not excessive in weight. The disadvantages were inefficiency in steam consumption, inaccessibility for repair and cleaning, and excessive vibration.

In 1889 horizontal engines were abandoned in favor of the vertical type. The first vertical engines were two cylinder noncondensing, designed for an initial steam pressure of 80 pounds, cranks at 90°, but the pounding which resulted made necessary the spacing of 180° between cranks in subsequent designs.

The dynamos direct connected to these engines were 4-pole machines with field coils on the vertical and horizontal axes bringing the lower field coil into a position where it was subjected to oil and water, and much trouble was experienced with this coil in this arrangement of poles.

The valve chests were located between the cylinders, mainshaft bearings being provided between the cranks and eccentrics, thus giving five bearings to the sets, four on the engine proper and one on the commutator end of the shaft. The latter bearing was of the self-oiling ring type, the others being lubricated by oil cups. Oval wear in the cylinders developed in

these sets, due to rocking of the piston, *i. e.*, lateral play, existing in the cross heads. This was at first remedied by the use of tail rods and later by a new design of crossheads and guides, and the use of conical pistons. The engine and armature shafts were in common, and it was almost impossible to remove and replace the armature without springing the shaft. The defects developed in service in these sets were soon overcome, the poles were spaced diagonally on the field frames and the engine and dynamo shafts were no longer made combination, but joined by flanged couplings securely bolted, and the driving communi-

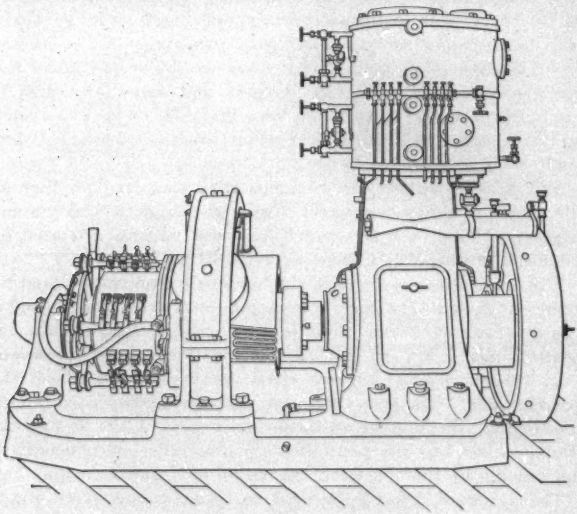


FIG. 2.

cated by a cross-key through a key-way common to both faces of the shaft flanges.

Tandem compound engines have been used extensively and were first installed on the U. S. S. *Chicago*. They are shown in Figs. 2 and 3. They have given excellent results, although not as efficient noras accessible as the cross-compound engine required by the present specifications. The excessive height of this type of generator, not only assembled, but the additional head-room necessary to remove pistons and rod, prohibits their use in naval

installations with the comparatively small height between decks. Fifty kilowatts would seem to be the maximum capacity allowable in generators of this design, and they could only be used in a majority of vessels by making special provision for the removal of pistons.

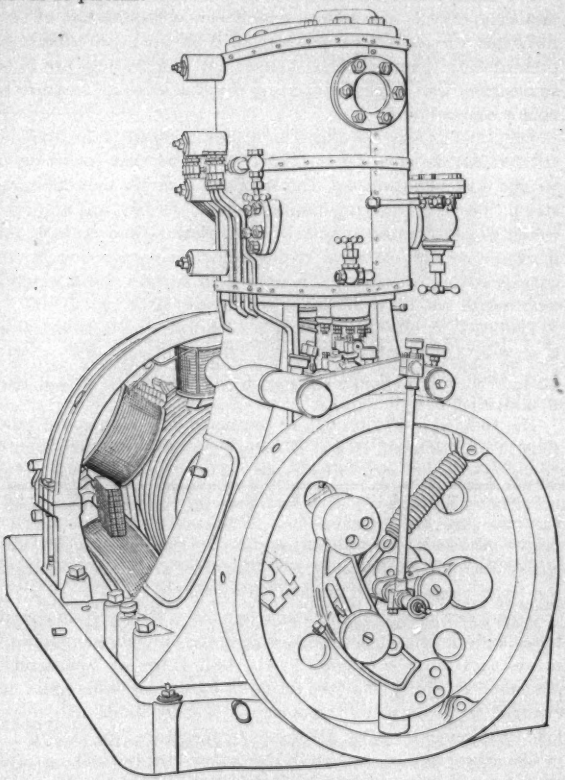


FIG. 3.

Lubrication in the steam spaces is not allowed, as the auxiliary boilers in some cases have been injured and the crown sheets dropped in spite of the precaution of removing oil from condensed steam. To lessen further the liability of oil working into

the cylinders, the stuffing boxes are specified to be at least as long as the length of stroke of engine. These boxes are to be accessible from the outside of the enclosing casing of the engine to facilitate adjustment.

Forced lubrication is an essential factor in attaining satisfactory operation of a generator, and is now required on all sets furnished the navy. A pressure of from 10 to 20 pounds is prescribed in the lubricating systems, but the bearings are to be so designed that forced lubrication is not a necessary feature to insure cool running.

The smaller sets, 2½ and 5 k. w., for torpedo boats and destroyers are designed for high speed, in order that reduction in weight may be attained. This involves a rather uneconomical steam consumption, but inasmuch as these sets are not subjected to continuous running, as in battleships and cruisers, the increased weight of steam required for their operation is not considered in the attempt to reduce all torpedo boat weights to a minimum.

The 2.5 k. w. sets give an output of 5 watts per pound, the 5 k. w. sets 3.865 watts per pound, although some 5 k. w. sets have been installed with an output of 5 watts per pound weight of set.

The 16-k. w. sets, although of comparatively high speed (400 to 500 r.p.m.) show a weight efficiency rather lower than would appear consistent with other types. These sets give 2.86 watts per pound, whereas the 32 k. w. sets give 3.14 watts and the 100 k. w. sets 4.55 watts per pound. The specified water consumption of all sets is rather liberal, as it is the aim to secure fair efficiency with great durability, and sacrifices are made to ensure the latter characteristic in naval installations.

Generators have improved step by step with the commercial type, and the specifications now in force embody no requirements that are not fulfilled by the best types of commercial machines, excepting that the rating of these generators must be changed to conform to the specified heating limits and overload requirements. An allowable temperature rise of 33⅓° C. in armature appears at first sight rather low, but taking into consideration the high temperatures in many of our dynamo-rooms in tropical service, the low heating limits assigned are justifiable.

A two-hour overload of 33⅓% is specified in order that a machine running at or near full load may be capable of handling

a sudden call for a motor load or searchlight, thus obviating the delay caused by being compelled to start a new machine.

The present specifications issued in November, 1901, based on experience, are outlined as follows:

Each set to consist of an electric generator direct-coupled to a steam engine, both mounted on a common bed-plate.

The sets as a whole shall be as compact and light as is consistent with a due regard to strength, durability, and efficiency. The standard sizes with their corresponding maximum allowable speeds, weights and over-all dimensions are:

TABLE 1.

Size in kilowatts.	Revolutions per minute.	Weight in pounds.	Length in inches.	Width in inches.	Heightin inches.
2.5	800	500	32	20	30
5	750	1,300	50	28	40
8	550	2,500	64	34	50
16	450	5,600	78	40	60
24	400	7,300	88	48	68
32	400	10,000	101	52	78
50	400	16,000	110	60	85
100	350	22,000	125	70	95

The design shall provide for accessibility to all parts requiring inspection during operation, or adjustment when under repair. Sets are to be designed to operate right-handed, *i. e.*, counter clockwise when facing the commutator end, or left-handed, as required. The design to be preferably such that the same parts may be used in each, in order to avoid increase in number.

The sets must be capable of running without undue noise, excessive wear or heating. Must be balanced and run true at all loads up to 33⅓% above rating; must be capable of running for long periods under full load and without continued attention.

Cast or wrought iron shall not be used for bearing surfaces, except in cases of cylinders, valve chests, and crosshead slides. Both upper and lower halves of main bearings to be removable without removal or displacement of shaft.

The driving shaft must be fitted with thrust collars or other suitable device which will prevent a movement of the shaft in the direction of its length, as might be caused by the rolling of the ship.

The combination bed-plate to be a substantial casting, and provided with accurately spaced drilled holes for securing to foundation.

An oil groove of ample width and depth to be cast in the upper flange of bed-plate, to be continuous around the engine and to be provided with a stopcock for drainage. The lower side of the combination bed-plate to be planed perpendicular to the line of stroke of engine.

Seats for all boltheads and nuts to be faced. All nuts to be case-hardened, and to be U. S. standard sizes. Where liable to

work loose from vibration, nuts are to be secured by use of jam nuts and spring cotters. All bolt ends to be neatly finished. The two halves of the main coupling to be either keyed to, or forged solid with the engine crank and armature shaft. The coupling to be bolted together by well-fitted bolts, driving to be done by a cross-key set in the faces.

ENGINE.

Engines are to be of the automatic cut-off vertical inclosed type, designed to run condensing with maximum practical efficiency at all loads, but capable of satisfactory operation when running non-condensing; to be of sufficient indicated horsepower to drive the generator for an extended time at the rated speed, when said generator is carrying a one-third overload.

Sizes 2½ k. w.,5 k. w., and 8 k. w., to be simple engine, single or twin cylinder at the option of the contractor. Sizes of 16 k. w. and above to be cross-compound with cranks set at 180°.

The normal steam pressure under which the engine, running condensing with 25-inch vacuum for different size sets, is to operate, and the maximum allowable water consumption per kw. hour output of the set are:

TABLE 2.

K.W.	Normal steam pressure.	Water consumption per K.W. hour, full load.
2.5	100	105
5	100	90
8	100	65
16	100	44
24	100	40
32	100	37
50	100	35.5
50	150	33.5
100	150	31

In testing, correction shall be made by calorimeter for entrained moisture. Superheating shall not be used in the test.

Engines must run smoothly and furnish the required power for full load at any steam pressure within 20% (above or below) of those given above and exhausting either to condenser at 25 inches vacuum or to the atmosphere. Must be able to bear without injury the sudden throwing on or off of one and one-third times the rated full load of the generator, by making and breaking the generator's external circuit.

The length of stroke of the engine to be not less than the diameter of the bore of the high-pressure cylinder.

The cylinders to be made of hard, close-grained charcoal iron, bored and planed true, of sufficient thickness for operation after re-boring once, steam and exhaust ports to be short, of ample area and free from fins, scales, sand, etc. Cylinders to be fitted with the usual drain cocks, all drains to end in one outlet. In addition to these drains, relief valves are to be fitted to each end

of each cylinder, and both high-pressure and low-pressure valves are to be free to lift from their seats to relieve the cylinder of water.

The low-pressure cylinder must be fitted with a flat, balanced slide valve; a piston valve on the low-pressure cylinder will not be accepted.

The pistons to be of cast iron or steel, strongly ribbed, light and rigid, and fitted with self-adjusting rings, each piston to have two or more rings. Rings to override counterbore of cylinders, to prevent wear to a shoulder.

Piston rods to be of forged steel securely fastened to pistons and crossheads. Crossheads to be of steel with adjustable shoes. Connecting rods to be of steel with removable babbitt-lined boxes for crank pins and bronze boxes for crosshead pins.

The crank shaft to be forged in one piece; counterweights for balancing reciprocating parts to be forged with it or securely fastened thereto. Valve rods, eccentric rods, and rocker shafts, as well as all finished bolts, nuts, etc., to be of best forged steel.

The governor to be of the weight and spring type, arranged to operate the high-pressure valve by a shifting eccentric, thus automatically varying the valve travel and point of cut-off. No dash-pots or friction washers shall be used in its construction.

The speed variation must not exceed 2½% when load is varied between full load to 20% of full load, gradually or in one step, engine running with normal steam pressure and vacuum. A variation of not more than 3½% will be allowed when full load is suddenly thrown on or off the generator, with constant steam pressure either normal, 20% above, or 20% below normal, and exhaust either to condenser or to atmosphere. No adjustment of the governor or throttle valve during the test shall be necessary to ensure proper performance under any of the above conditions.

Stuffing boxes for piston rods to be slightly longer than length of stroke, in order that no part of the rod exposed to the oil in the enclosure will enter the cylinders. Stuffing boxes for piston rods and valve rods to be accessible from the outside of the enclosing case of the engine.

A guard plate to be provided to prevent oil from being thrown against the lower cylinder heads and valve chests.

Engines are required to operate satisfactorily without the use of lubricants in the steam spaces. The lubrication for all other working surfaces shall be of the most complete character. No part shall depend on squirt-can lubrication.

Forced lubrication shall be used wherever practicable, which includes engine shaft, crank pins, crosshead bearings, eccentric, etc. The engine shall be capable of satisfactory operation with a low grade of lubricating oil, and the forced lubrication shall not be a necessary factor for its cool and satisfactory running. The intent of the forced lubrication is to reduce friction, noise and attention required.

The pressure for such forced lubrication shall be approximately 15 pounds per square inch, and shall be between 10 and 20 pounds under all service conditions.

The bed-plate is to contain a reservoir and cooling chamber of ample capacity, to be provided with a strainer which may be removed without interrupting the oil supply. The pump is to be direct-driven by a crank or eccentric on the engine shaft, construction to be simple and durable, and to include a proper guide or support for the plunger rod. The pump to handle clean oil only, not drawing from the top or bottom of reservoir.

GENERATOR.

To be of the direct current, multipolar type, compound-wound long-shunt connection, designed to run at constant speed and to furnish a pressure of 125 volts at the terminals, at rated speed, with load varying between no load and one and one-third times rated load.

The magnet yoke or frame to be circular in form, to have inwardly projecting pole-pieces, and to be divided in half horizontally, in all generators above 5-k.w. capacity, the two halves being secured with bolts, to allow the upper half with its pole pieces and coils to be lifted to provide for inspection or removal of armature. Pole pieces to be bolted to frame, bolts to be accessible in assembled machine to enable removal of field coils without disturbing armature or frame. Magnet frame to be provided with two feet of ample size to ensure a firm footing on the foundation.

Facilities for vertical adjustment of frame to be provided in sizes of 16 k.w. and above.

Armature spider to be designed to avoid shrinkage strains; to be accurately fitted and keyed to shaft and to have ample bearing surface thereon.

The disks or laminations to be accurately punched from the best quality of thoroughly annealed electrical sheet steel, slots to be punched in periphery of laminations to receive armature windings. Disks to be magnetically insulated from one another, and securely keyed to spider or held in some other suitable manner to obviate all liability of displacement due to magnetic drag, etc. Space blocks to be inserted between laminations at certain intervals to provide ventilating ducts for cooling the core and windings.

Laminations to be set up under pressure and held securely by end flanges. Bolts holdings these end flanges must not pass through laminations.

The commutator bars or segments to be supported on a shell, which must be either part of, or directly attached to the spider, to prevent any relative motion between the windings and these segments. Bars to be of hard drawn copper finished accurately to gauge. Insulation between bars to be of carefully selected mica and not less than 0.03 inch thick, and of uniform thickness throughout.

Bars to line with shaft and run true, to be securely clamped by means of bolts and clamping rings. Bolts to be accessible for tightening and removable for repair.

Brushes to be of carbon. In sizes over 5 k.w. there shall be not less than two brushes per stud, each brush to be separately removable and adjustable without interfering with any of the others. The point of contact on the commutator shall not shift by the wearing away of the brush.

Brush holders to be staggered in order to even the wear over entire surface of commutator; the generator to be provided with some device for shifting all the holders simultaneously. All insulating washers and brushes to be damp proof and unaffected by temperature up to 100° C.

Finished armature to be true and balanced both electrically and mechanically, that it may run smoothly and without vibration. The shaft to be provided with suitable means to prevent oil from bearings working along to armature.

All copper wire to have a conductivity of not less than 98%.

The shunt and series field coils to be separately wound and separately mounted on the pole-pieces. The shunt and series coils, respectively, of any one set to be identical in construction and dimensions and to be readily removable from the pole-pieces.

The testing voltage for sets under 16 k.w. shall be 1,000 volts and for sets of 16 k.w. and above shall be 1,500 volts, and the source of the alternating e.m.f. shall be a transformer of at least 5 k.w. capacity for sets of 50 k.w. and under, and of at least 10 k.w. capacity for sets of greater output than 50 k.w.

The test for dielectric strength shall be made with the completely assembled apparatus and not with its individual parts, and the voltage shall be applied between the electric circuits and surrounding conducting material.

The tests shall be made with a sine wave of e.m.f., or where this is not available, at a voltage giving the same striking distance between needle points in air, as a sine wave of the specified e.m.f. As needles, new sewing needles shall be used. During the test, the apparatus shall be shunted by a spark gap of needle points set for a voltage exceeding the required voltage by 10%.

With brushes in a fixed position there shall be no sparking when load is gradually increased or decreased between no load and full load; no detrimental sparking when load is varied up to one and one-third times rated load; no flashing when one and one-third load is removed or applied in one stage.

The jump in voltage must not exceed 15% when full load is suddenly thrown on and off.

The temperature rise of the set after running continuously under full rated load for four hours must not exceed the following:

TABLE 3.

	Method of measurement.	Maximum allowable rise in °C.
		°
Armature	Electrical	33½
Commutator	Thermometer	40
Field coils	Electrical	33½
Shunt rheostat	Electrical	75
Series shunt	Thermometer	40

The rise of temperature to be referred to a standard room temperature of 25° C. and normal conditions of ventilation. Room temperature to be measured by a thermometer placed 3 feet from commutator end of the generator with its bulb in line with the center of the shaft.

The generator to be capable of satisfactory operation for a period of two hours, carrying one and one-third times its rated full load, and no part shall heat to such a degree as to injure the insulation.

Generators of the same size and manufacture to be capable of operation in parallel, the division of the load to be within 20% throughout the range. The magnetic leakage at full load shall be imperceptible at a horizontal distance of 15 feet, measurements to be taken with a horizontal force instrument.

The minimum allowable efficiencies of the generators are as follows:

TABLE 4.

K. W.	Loads.			
	1¼.	1.	¾.	½.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
2.5	78	78	76	73
5	80	80	78	75
8	84	84	83	80
16	87	87	86	84
24	88	88	87	85
32	88	88	87	85
50	89	89	88	86
100	90	90	89	87

The cross-compound type of engine now used exclusively in the new installations for sets above 8 k. w. shown in Fig. 4, which gives sectional plans of dynamo engines for the *Wisconsin*, designed and manufactured by the Union Iron Works. Cylinders 8½″ and 13½″ diameter; stroke 8″ r.p.m. 400; initial steam pressure 100 lbs.; h.p. 50; over-all dimensions, length 8′ 3.5″, width 3′ 7″, height 6′ 3″.

Fig. 5 shows multipolar 8-pole, 24 k. w., 400 r.p.m., 80-volt, generating set manufactured by the General Electric Company

for the *Olympia*. The details of this generator and the tabulated result of test are as follows: Weight, 9,385 lbs., complete; extreme length 84″; extreme width, 52″; extreme height, 77½″ over all; number of cylinders, two; cranks at 180°; inertia governor, steam pipe 2½″; exhaust pipe 4″; diameter high pressure cylinder 7½″; diameter low pressure cylinder 12″; stroke 8″.

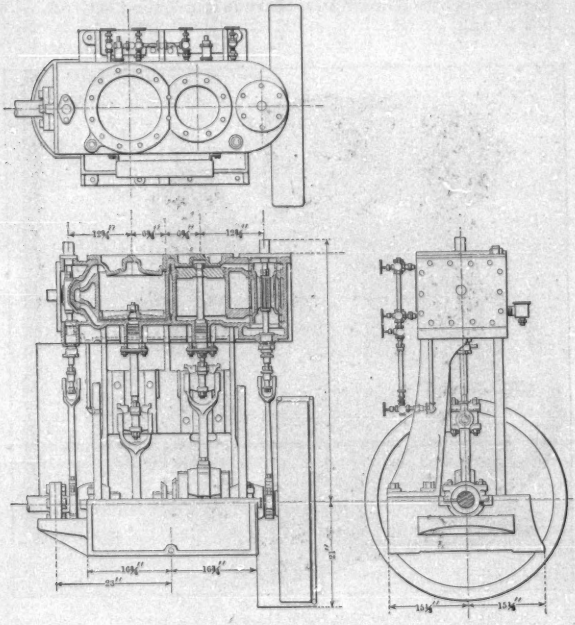


FIG. 4.—Engine 8½″ x 13½″ x 8″ stroke for 32 k.w. Dynamo.

Dynamo dimensions: Volts 80°; amperes 400; r.p.m. 400; poles 8; number of carbons per brush 1; dimensions of brushes 1¼″ x ⅝″.

TESTS.

Heat run.—4 hours at 394 amperes. Terminal volts 81.8 to 81.5; steam 100 lbs; vac. 22 to 21.5; r.p.m. 406; temperature air 28.2° C. at beginning, 30.2° C. at end of run.

Temperature at end of heat run: Armature core surface,

51°C.; commutator bars, 55.5°C.; pole tip leading, 47.5°C.; pole tip trailing, 48°C.; main bearings, 52°C.

Overload run, two hours at 33⅓% overload. Temperature of air during run, 30°C. Temperatures at end of run: armature core surface, 59.5° C.; commutator bars, 59.5°C.; pole tip leading, 53.5°C.; pole tip trailing, 54° C.

Average water consumption during four hour heat run, 33.6 per k.w. hour.

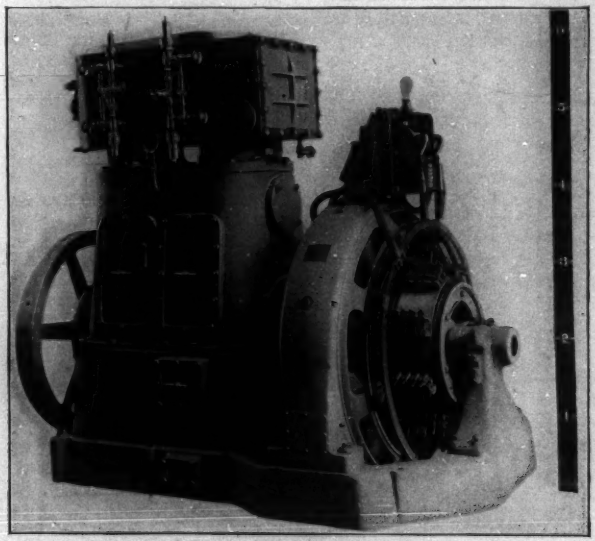


FIG. 5.—MP 8–32–400–80 Volt Form D Generating Set, with 7½″–12″ x 8″ Cross-Compound Form H General Electric Engine.

OUTPUT AND EFFICIENCY.

$I^2 R$ brush, 768 watts.	Volts, 80.
$I^2 R$ armature, 1,600 watts.	Amperes, 400.
$I^2 R$ series, 422.4 watts.	Input, 32,000 watts
C. E. shunt, 753.3 watts.	
Core loss and friction, 1,637 watts.	Losses, 5,180 watts.
Total losses, 5,180.7.	Outputs, 37,190.7 watts.
	Efficiency, 86%.

ENGINE REGULATION.

TABLE 5.

Full load to no load.

Revolutions.			Volts.			Amperes.	Steam.	Vacuum.
Steady.	High.	Low.	Steady.	High.	Low.			
410	435	415	81	91	81	0	100	21.5
415	410	405	81	81	72	400	100	22.0
410	436	415	80.8	92	81	0	100	21.5
415	410	405	81	81	72	400	100	21.5
410	435	415	80.8	91	81	0	100	21.5
415	410	405	81.1	81	72	410	100	21.5

Average difference, 5.
Average difference per cent., 1.25.

TABLE 6.

Compounding Test—Hot.

Armature.		Field.		R. P. M.	Steam.	Vacuum.
Volts.	Amps.	Volts.	Amps.			
81.2	0	64	12.27	415	100	22.5
81	405	64	12.29	410	100	22.5
82.3	303	65	12.49	412	100	22.5
82.6	202	65.2	12.52	415	100	22.5
82.4	101	64.8	12.43	416	100	22.5
81.2	0	64.0	12.29	416	100	22.5
81.2	101	64.0	12.29	414	100	22.5
81.5	202	64.5	12.31	412	100	22.5
81.5	303	64.5	12.32	412	100	22.5
81	405	64.0	12.29	410	100	22.5

SWITCHBOARDS.

Switchboards are designed to give great flexibility to the distribution of electric energy and admit of a variety of combinations of generators. The present boards are more uniform in design than in the old installations, and a standard has finally been adopted which may be used for any number of dynamos.

The design of the switchboard in general is such that any dynamo or combination of dynamos operating in parallel may be run on any circuit or combination of circuits. These circuits are: search-light, light, power, and one for each electrically operated turret, the operation of the turning mechanism of which requires a separate dynamo.

In the larger installations, the switchboard has a generator panel, a lighting distribution panel, a power distribution panel and a searchlight panel. The first three are continuous and form one board, the last is separated from the main board. When the installation consists of two generating sets only, the lighting distribution panel and power distribution panel, and, when space permits, the searchlight panel may be combined.

The switchboard is arranged for connecting the negative lead

of each machine to a horizontal common negative bus-bar, by a single-pole, single-throw switch. When the dynamos are more than three in number, each one is arranged for connection to either of two horizontal equalizer or bus-bars by means of single-pole, single-throw switches. For installations of three dynamos only, one equalizer bus-bar is necessary, and for two dynamos a single equalizing switch is used.

The positive lead of each dynamo connects to a vertical bus-bar. The circuits, five in number, each lead from a separate horizontal bus-bar. At each crossing of these two sets of bus-bars (the number of points will be the product of the horizontal and vertical bus-bars), connections can be made by means of single-pole, single-throw switches, placed horizontally. Switches all hinge from dynamo bus-bars and throw to the left.

The arrangement of the dynamo panel is such that all the switches and instruments (except voltmeters) necessary for the control of one dynamo are in a vertical line, and consists of (starting from the top) a single-pole automatic circuit-breaker, an ammeter shunt, an ammeter handle for operating field regulator, voltmeter receptacle, such field controlling switches as the turret turning system requires, positive dynamo switches connecting to circuit bus-bars, switch to common negative bus-bars, switches to equalizer bars, and last, a switch for shunting around the series field of dynamo when turret turning system so requires.

The arrangement of the voltmeters allows the voltage of any dynamo to be read on either of two voltmeters, allows all the voltmeters to be interconnected for calibration and allows the simultaneous reading of the voltage of any or as many dynamos as it may be desired to connect in parallel at any one time.

The power distribution panel contains a double pole switch, fused, for each motor circuit, a main negative power switch, a main negative switch for each turret-turning circuit, and such other auxiliary switches as the turret-turning system may require.

The light-distribution panel contains a double-pole switch, fused, for each lighting circuit, a main negative lighting switch, and when a separate searchlight panel is used, the light distribution panel contains a main negative searchlight switch.

The switchboard is to be provided with a lamp ground-detector with a switch for breaking ground connection. In addition, a voltmeter ground detector is to be provided with leads to a selective plug receptacle to assist in determining circuit which the ground is on. All switches and bus-bars are of hard

drawn pure copper, with conductivity not less than 96%. When the hinge carries current,s witches are provided with spring hinge washers, with ready means of adjusting them. All circuits terminate and all connections are made on the back of the board. Name plates are secured to the board near the circuit switches showing the serial number of each circuit and the character and location of its load.

Ammeters and voltmeters for generating sets are marked with the number of the set; ammeters and voltmeters for searchlight circuits are marked with the name and number of the particular light.

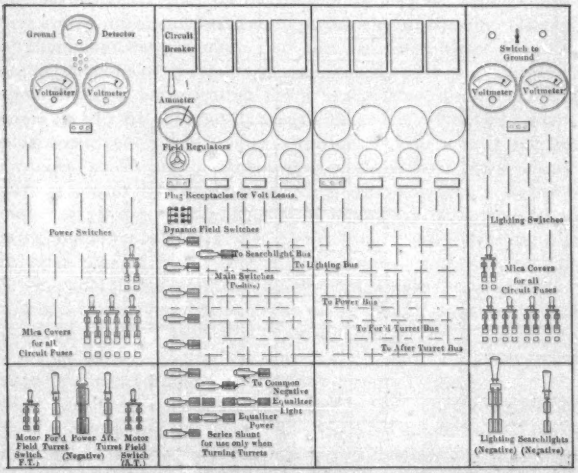


FIG. 6.—Standard Switchboard, 8-Dynamos, 5-Circuit Bus Bars, showing Arrangement and Switch and Instrument Locations.

Faces of slate panels are finished with black enamel. Panels are at least 1½″ thick, supported by a frame of all steel construction and secured thereto by through bolts.

Figs 6 and 7 show the standard switchboard adopted for future installations. This board is similar to the type to be installed in the *Maine*, *Missouri* and *Ohio*. The circuits are five in number, including separate circuits for each electrically turned turret. For paralleling the dynamos, there are two separate equalizer bus-bars, one for lighting and one for power.

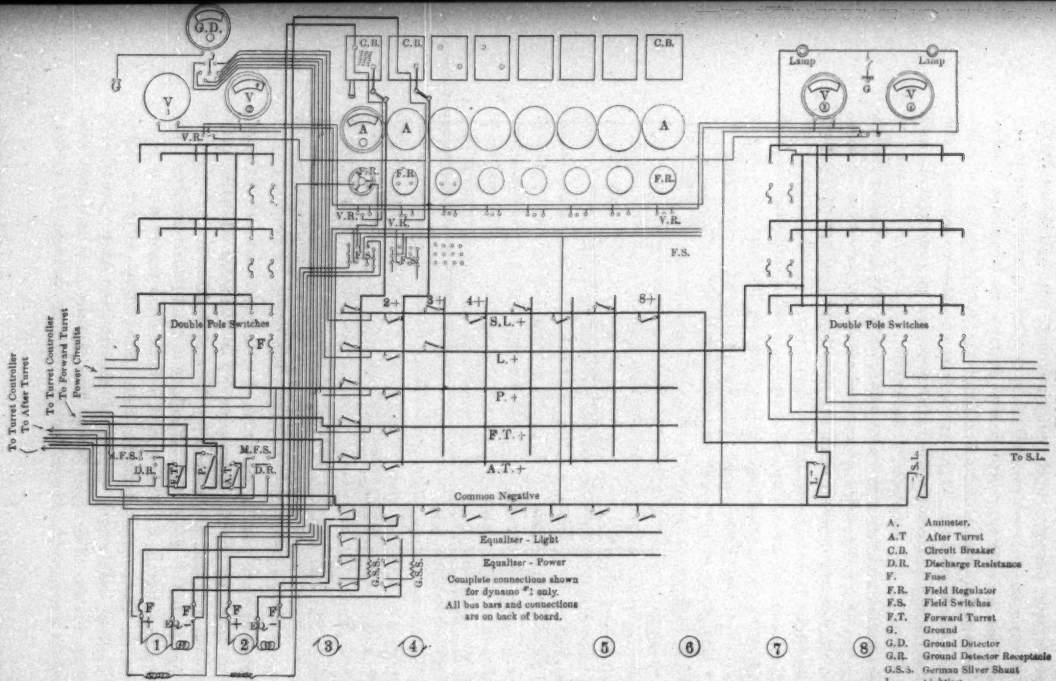


FIG. 7.—Diagrammatic Sketch of Standard Switchboard, arranged for 8-Dynamos and 5-Circuit Bus Bars.

There is no occasion for paralleling machines on searchlight or turret-turning circuits. Such dynamos as may be desired are connected to these equalizer bus-bars by removable blade plug switches.

When a dynamo is used to operate a turret-turning motor, the series field is short-circuited through a special German silver shunt, in addition to the shunt used on the dynamo itself. This is accomplished by a single-pole, single-throw switch at the base of the board, one switch to each machine. Referring to Fig. 6, each of the two dynamo panels is arranged in four vertical sections, each section containing all the apparatus necessary for the operation of one dynamo. Starting at the top, we have a single-pole automatic circuit-breaker on positive leg of dynamo (handle of circuit-breaker not more than six feet from deck), then the ammeter shunt on the back of the board, next the ammeter, then the wheel for operating the field regulator, the wheel being connected to the rheostat by a sprocket chain. Next comes the plug receptacle for voltmeter connections, then field control switches, consisting of three pairs of single-pole, single-throw switches, next five single-pole, single-throw positive dynamo switches, by means of which the dynamo may be connected to searchlight bus, lighting bus, power bus, forward turning bus or after turning bus. In the same vertical row, but on the lower panel, there are four single-pole, single-throw switches; the upper one connects the negative leg of the dynamo to the common negative bus-bar, the two middle switches connect to the equalizing bus-bars; the lower switch is to shunt the series field for turret turning.

At the left of the generator panel is the power distribution panel, containing as many double-pole, single-throw fused switches as may be required. Arranged at the top of this panel is a ground detector with selective plug receptacle, also two voltmeters with plug receptacle underneath. In the center of the power panel is a main negative power switch, single-pole, single-throw, while on each side are two single-pole, single-throw switches controlling the negative legs of the turret-turning circuits. The left hand switch is for the forward turret, and the right hand switch for the after turret. Again outside of these last mentioned switches are the field switches of the turret motors and the dynamos used for turret turning. These are double-pole, single-throw switches, with an extra set of long switch clips, across which is connected a field discharge resistance.

To the right of the generator panels is the lighting distribution panel, containing as many double-pole, single-throw switches as may be required. At the top of this panel is an ordinary lamp ground-detector with a small single-pole, single-throw switch to break the ground connection (this being necessary before using detector on power panel). This panel also contains two voltmeters with plug receptacle underneath. On the lower panel are two single-pole, single-throw main negative switches, one for lighting circuits and the other for searchlight circuits. Each dynamo contains on its headboard a main fuse on its positive leg. The field-control switches allow three methods of field excitation. By throwing the two upper switches, the machine is made self-exciting. By throwing the two middle switches, the machine is separately excited and controlled from the forward turret. By throwing the two lower switches, the machine is separately excited and controlled from the after turret.

The voltmeter connections are shown in Fig. 7. The plug receptacle on the power panel and the four receptacles on the left hand dynamo panel for machines 1, 2, 3 and 4 have a spacing of 1″ and 2″, whereas the receptacle on the lighting panel and those for machines 5, 6, 7 and 8 have a spacing of 1½″ and 2½″. By using the 1″ plug in any receptacle on the dynamo panels, the voltage of the machine is read on voltmeter No. 1; by using the 2″ plug the voltage can be read on voltmeter No. 2; thus we can read the voltage of any two machines on the left-hand panel and of any two machines on the right-hand panel simultaneously. With the 2″ plug in a receptacle on the dynamo panel and the 1″ plug in the receptacle on the power panel we have voltmeter No. 1 in parallel with voltmeter No. 2 for calibration. With the 1″ plug in any receptacle on the dynamo panel, the 2″ plug in the receptacle on the power panel and the 1½″ plug in the receptacle on the lighting panel voltmeters Nos. 1 and 3 are in parallel. By substituting the 2½″ plug for the 1½″ plug in the above arrangement, voltmeters Nos. 1 and 4 are in parallel. As only one plug of each spacing is to be furnished, it is impossible to make a short-circuit or parallel two machines on the voltmeter connections. An inspection of Fig. 7 shows this to be true.

When starting up a new machine to be paralleled with the one already running, the operation at the switchboard is as follows: First, close circuit breaker; Second, close equalizer switch; Third, close switch to common negative; Fourth, plug to voltmeter and adjust voltage by field regulator; Fifth and last, close positive switch.

For detecting grounds, the lamp detector on the upper part of the lighting panel is connected permanently across the common negative bus, and the positive leg on the lighting circuit panel; add when using the ground detector on the power panel, the ground connection on this lamp detector must be broken. The connections to this ground detector (on power panel) are such that when a circuit is grounded on the positive leg, the instrument will indicate when plugged to negative; and for a ground on the negative of any circuit, the instrument will indicate when plugged to any of the positive circuit bus-bars, provided, of course, that said bar is alive, and here it should be noted that a bar is alive when any switch in the horizontal row connecting to it, is thrown.

To locate a ground in the quickest possible manner, the group switches, *i. e.*, main negative and positive dynamo switches on the lighting circuit, should be opened; if the ground still appears the switches should be closed and the corresponding switches on each circuit opened (one circuit at a time) until the ground disappears. When the ground is singled down to one group, the circuit-switches on this group should be opened one at a time until the defective circuit is found.

CIRCUITS, WIRE AND WIRING APPLIANCES.

Circuits are installed on the main and feeder system. The feeders are connected to terminals on the switchboard and feed the mains as nearly as possible at the center of the load.

All wires for feeders, mains and branches are installed in enameled steel conduit except in passages and dynamo rooms, if not exposed to mechanical injury, when porcelain racked hangers are allowed. Moulding is no longer used except in officers' quarters or over hardwood surfaces, for the sake of appearances. All feeders as far as possible run below the water line. Thorough water-tightness is observed for all leads into wiring appliances and fixtures and through all water-tight decks and bulkheads.

The conduit is secured to the metal of the ship by stout metal straps, and the wiring appliances are usually supported in place by the conduit. Conduit is made water-tight internally when necessary to prevent the flow of water from one compartment to another. For wire of below 60,000 c.m., cross-section twin conductor is run in the same conduit; above this size, two leads o conduit are used, one for each leg.

Circuits are divided into three classes, each being entirely distinct from the others: (1) searchlight circuits; (2) lighting circuits; (3) motor circuits.

Each searchlight is provided with a separate feeder from the switchboard through a double-pole switch, fused, rheostat, ammeter and double-pole automatic circuit-breaking device direct to the terminal lead of searchlight pedestal. A rheostat in a non-combustible frame is supplied for each search-light. The rheostat has a dead resistance which, when heated, gives a drop of from 55 to 65 volts, and also an adjustable portion in not less than ten divisions, each giving a drop of one volt for the normal current of the lamp. The value of the dead resistance depends on the size of the searchlight, large lights requiring higher voltage across the arc than the smaller ones, and this value is such that with 125 volts on the dynamo side, the variable resistance will give at the search-light from four volts below the best working voltage of the lamp to six volts above the best working voltage The maximum allowable rise in the rheostat is 75° C.

The feeders are of the following sizes:

13″	18,081 c.m.
18″	30,856 c.m.
24″	38,912 c.m.
30″	60,088 c.m.

Lighting circuits are divided into these two classes, each class having separate feeders and separate mains.

(a) Battle service.

(b) Lighting service.

Battle service includes every light installed below the protective deck and all lights above the protective deck which are necessary during action. This includes lights for the operation of guns, at ammunition hoists, boat-cranes, at controllers, ni military tops, on searchlight platforms, in conning tower, in signal tower, in limits, chart-house, signal and running lights, compass light, lights at main blowers above the protective deck, and such light as may be necessary to allow access to compartments and passages in action.

Lighting service includes all lights not above enumerated. The maximum load on lighting feeders does not usually exceed 75 amperes. The area of cross-section of the feeders and mains is such that the fall of potential from the dynamo terminals to the most distant outlet is not more than 3% at the normal load of the feeder. No feeder or main has a cross-section that will give a greater current density than one ampere per 1,000 c.m. All reductions in size of feeders or mains are fused and wherever

mains are led off from feeders, it is done through standard feeder junction-boxes, having double-pole fuses, which blow on the basis of one ampere per 500 c.m. of the main. The branch outlets are fused for the normal rated load of three amperes and blow at six amperes. Fuses for feeders and mains are at the rate of one ampere per 1,000 c.m. and blow at one ampere per 500 c.m.

Motor Circuits.—Motors the normal full load circuits of which are less than 50 amperes are grouped on one feeder, and this procedure is followed up to a total load of 100 amperes. Large motors with full working load exceeding 50 amperes are installed with a separate feeder. The area of the cross-section of the feeders for motors is such that the fall of potential from dynamo terminals to motor terminals does not exceed 5% at normal full load.

Mains from motor feeders pass through feeder junction-boxes having double-pole fuses. Where several mains lead from the same feeder at one point a distributing panel with double-pole fuses is installed. All motor feeders and mains have a cross-section of not less than 1,000 c.m. per ampere for continuous service, and 500 c.m. per ampere for intermittent service.

Wire.—The wire used for electric circuits in the early naval installations consisted of a solid copper conductor covered with three layers of cotton braid, the inner one soaked in a bituminous composition, the outer one painted. In addition to the above protection, branch wires were tinned and covered with a rubber coating. This wire proved inefficient, the salt water finding its way to the conductor. To protect the conductor from this action, a lead covering was next introduced. The circuits were secured by iron staples usually without moulding.

A further step in the line of progress was made by using a tinned conductor wrapped with cotton thread, then a preparation of rubber with paraffined cotton braiding, the whole being protected by a lead sheathing. Fibre staples were used, a special tool being required to set them in place. Salt water found its way into these conductors where they passed through decks and bulkheads, whereas sections over boilers were thoroughly baked, resulting in disintegration of the insulating material and grounding of the lead covering. Specifications for the next installations required copper to be tinned, insulated by cotton wrapping, a layer of white rubber, and then the lead sheathing as before. Previous experience has shown the larger size conductors to lack flexibility and to tend toward rupturing

the lead sheathing at bends, and accordingly stranded conductors for the larger circuits came into vogue.

This wire was further improved by interposing a layer of pure Para rubber between the cotton wrapping and the vulcanized rubber. For this style of wire an insulation resistance of 1,000 megohms per mile was specified for a sample 500 feet long, after immersion in sea water for 24 hours.

The next step in the evolution of wire for ships' use consisted in coating the conductor with a heavy layer of cotton braid saturated with insulating compounds, which covering replaced the lead sheathing, the rubber coverings being relied upon to exclude moisture. This latter wire gave satisfaction and frequently outlasted the mouldings in which it was installed. The wire in present use conforms to the following requirements: All conductors to be of soft annealed pure copper wire. When greater conducting area than that of 14 B. & S. G. is required. the conductor shall be stranded in a series of 7, 19, 37, 61, 91 or 127 wires, as may be required; the strand consisting of one central wire, the remainder laid around it concentrically, each layer to be twisted in the opposite direction from the preceding, and all single wires forming the strand must be of the diameter given in the American wire gauge table as adopted by the AMERICAN INSTITUTE OF ELECLRICAL ENGINEERS, October, 1893.

The material and manufacture of the strand must be such that the measured conductivity of each single wire forming the strand shall not be less than 98% of that of pure copper of the same number of circular mils, the measured conductivity of the conductor as a whole to be not less than 95% of that of pure copper of the same number of circular mils; each wire to be thoroughly and evenly tinned; all single lighting conductors shall be insulated as follows:

First. A layer of pure Para rubber, not less than 1/64″ in thickness, taped or rolled on; if taped, the tape to lap one-half of its width.

Second: A layer of vulcanized rubber about 3/32″ thick.

Third: A layer of commercial cotton tape, lapped to about 1/32″ in thickness.

Fourth: A close braid to be made of No. 20 2-ply cotton thread, braided with three ends for all conductors under 60,000 c.m., and of No. 16 3-ply cotton thread, braided with four ends for all conductors of and above 60,000 c.m. The outside diameter over the braid to be in exact conformity with that tabulated.

Tests.

The sample, after 24 hours immersion in sea water, must have an insulation resistance of not less than 1,000 megohms per nautical mile.

The test is to be at 72° F.

The sample is to be tested by the direct deflection method at a potential of not less than 200 volts.

Sample will be tested for a conductivity of not less than 95% of that of pure copper, having a cross-section of the specified number of circular mils.

Chemical tests will be made to determine the constituents of the different layers of the insulation.

Braid will be tested for waterproof qualities.

Physical tests will be first made for qualities of strength, toughness, dimensions, etc.

The physical and electrical characteristics of the insulation under change of temperature will be tested by exposing the finished conductor for several hours at a time, alternately, to a temperature of 200° F. (dry heat), and the temperature of the atmosphere, during a period of three days.

The tests for characteristics of the insulation will then be repeated, and must show no practical deterioration on the results of the former test.

All twin lighting conductors shall consist of two conductors, each one of which shall be insulated as follows:

First: A layer of pure Para rubber, not less than 1/64″ in thickness, taped or rolled on.

Second: A layer of vulcanized rubber about 1/16″ thick.

Third: A layer of commercial cotton tape, lapped to about 1/32″ in thickness.

Two such insulated conductors shall be laid together, the interstices being filled with jute, and covered with two layers of close braid.

Each braid is to be made of No. 20 2-ply cotton thread, braided with three ends.

The copper wire and tests of finished are conductor to be as specified for single conductor.

Motors.

Motor applications on board ships involve the use of all sizes of motors from 1/12 h. p. to 50 h. p. Fans for officers' quarters are of two sizes, 1/12 h. p. and 1/6 h. p., the former for 12-inch desk or bracket fans, the latter for 16-inch bracket fans. Small

¼ h. p. series motors are used on portable ventilating sets. These sets are necessary for temporary ventilation when working in such parts of the ship as are not reached by the main ventilating system.

The main ventilating system employs motors of all sizes from ¾ h. p., used with small exhausters, up to 15 h. p., which are used on the larger steel plate blowers. The controlling panels for these motors contain a double-pole line switch and a rheostatic starting-box with an automatic no-voltage and over-load release. A field rheostat for speed control is also mounted on the panel.

Ammunition hoists for 5-inch and 6-inch, and smaller guns, are either endless chain hoists or whip hoists, and are operated by shunt-wound reversible motors. A motor of about 3 h. p. is used for the endless chain hoist and motors as large as 6 h. p. are used on the whip hoists. The chain hoist motors as a rule are located below the protective deck. They drive through gearing and are controlled by a panel similar to those described for the blower motors, and in addition by a double-pole, double-throw reversing switch. These motors are fitted with solenoid brakes, which release when the lever is moved to first notch and set up when the lever is thrown to off position. Motors for whip hoists when located in exposed places on the decks or bridges, are made water-tight by means of iron plates over the hand holes set up against sheet-rubber gaskets. They are fed from the line through branch blocks and switches enclosed in water-tight boxes. An enclosed cylindrical reversible controller is used.

For turret guns chain hoists are also used, the motors being either suspended under the base of the turret or in the turret itself. These motors as a rule drive through a flexible cable, running over a drum on an intermediate shaft. Motors as large as 30 h. p. are required for the 12-inch mounts, motors of about 16 h. p. for the 10-inch mounts and 8 h. p. motors for the 8-inch mounts. The first two run at 350 r.p.m., the last at 400 r.p.m. Each gun in a turret has its own ammunition hoist motor. The controllers are operated by a single handle, capable of sudden reversal, and carry the load in either direction without change of speed. Automatic circuit-breakers are installed which break armature current only. The guns are elevated and depressed by shunt-wound motors of about 5 h. p. capacity, controlled in a manner similar to the ammunition hoist motors. For forcing the shell into the breech of the guns, rammer motors are used.

These motors are series-wound, and drive through a friction sheave so adjusted that in case the shell is set home before the motor is stopped, the slipping of the driving mechanism will hold the motor load down low enough to prevent the throwing of the circuit-breaker. These motors run at about 750 r.p.m., and are of 7 h. p. output for 12-inch mounts and 5 h. p. for 10-inch mounts. They carry the load in one direction only. Small motors are used to furnish air blast for clearing smoke out of the guns after firing.

Turrets are turned by motors operated on the Ward Leonard system, as at present installed, the use of a separate generating set being required for turning each turret. A system now under consideration embodies the use of a motor-generator for each turret, several of such motor-generators being supplied by one generating set. For 12-inch turrets, two 35 h. p. motors are installed, either one being capable of handling the turret alone. These motors, located diametrically opposite each other, drive a common cross-shaft through bevel gears, this shaft carrying near each end a separate worm, which actuates a pinion on a vertical shaft. The lower end of the vertical shaft carries a gear which meshes with an annular gear attached to the inner side of the barbette. The controller, located just under the sighting hood, is operated by one handle, and carries the load equally well in either direction. Automatic cut-outs are fitted at the limits of travel of the turrets.

Recent tests on turrets fitted as above show a nicety of control which is all that could be required. The turret was moved ten successive times, and only turned through an arc of 30.9 seconds. This would mean a single movement of 3.09 seconds, a distance scarcely discernible on the circumference of a 14-foot circle (the outside of the turret). The turret was turned throughout its range of travel, 136° starboard to 136° port, a total of 272° in less than 45 seconds. The weight of the mass moved was about 600 tons.

Boat-cranes as at present installed have but one motor for both hoisting load and revolving cranes, although on ships now under construction, separate motors will be used for each purpose. About 50 h. p. will be used on the larger cranes for hoisting and lowering, and about 25 h. p. for revolving the crane. The control of the hoisting motor is by means of a resistance continuously across the line, the speed being controlled by the amount of the resistance with which the armature is placed in

shunt. With this system, should the load on the crane tend to drive the armature at a speed in excess of that corresponding to the position of the controller handle, the armature will drive a current through the local circuit and run at constant speed unitl shut down.

In addition to the above-mentioned uses, motors are used to drive air compressors for use in torpedo work, such compressors requiring about 25 h. p., for closing water-tight doors; for lifting hatches; for dough mixers; for driving machine tools in the ships' workshops; for laundry work, etc. Electrically-operated steering gear and electrically-driven pumps are not used in our navy, although some foreign powers have applied the electric drive to such auxiliaries.

Interior and Exterior Signaling.

The means of interior communication consist of voice tubes, electric call-bells and annunciators, telephones, fire-alarms, general alarms, warning signal, engine telegraph, steering telegraph, helm indicator, revolution and direction indicator, battle and range-order indicators and transmitters. When a limited number of orders are to be transmitted, the telegraph is used; when an unlimited number of orders are to be transmitted and interior communication is necessary, telephones or voice pipes are installed, telephones being used for the longest leads. Between important stations, both telephones and voice pipes are installed. Call-bells and buzzers are used without returns for minor purposes.

The fire-alarm system comprises an annunciator, near the captain's cabin (under the eye of the cabin orderly) and thermostats located in coal bunkers, magazines and storerooms near the same. When the temperature in these places rises above 200° F., the alarm is given at the annunciator and the location is indicated. The thermostat in present use, Fig. 8, consists essentially of a helix of metal ribbon (metal having a large expansive co-efficient) and a terminal block, with an adjustable contact screw. Its operation is based on torsional strain produced in the helix by a rise in temperature, thus completing the circuit through the contact screw in the terminal block. The spiral embraces the shank of a " T "-shaped casting, the lower end of the spiral being connected to the lower end of the shank. The top of the spiral ends in a flat piece which extends across the top of the casting. One arm of the " T " is extended and is provided with a screw terminal for attaching live wire. The spiral ter-

minal is secured to an insulating plate of mica, Fig. 2, provided with a large hole in the center, through which the spiral is thrust, and other smaller holes by which it is secured to the spiral terminal, the other terminal and the bottom of the box.

The adjustable contact, Fig. 3, is a brass casting with an adjusting screw *a*, a screw terminal *b* for attaching the live wire, and two screws with washers *c* and *c* for securing the mica plate. A water-tight tube, Fig. 5, passes through a hole in the casting, Fig. 6, which forms the lower side of the conduit box, Fig. 7.

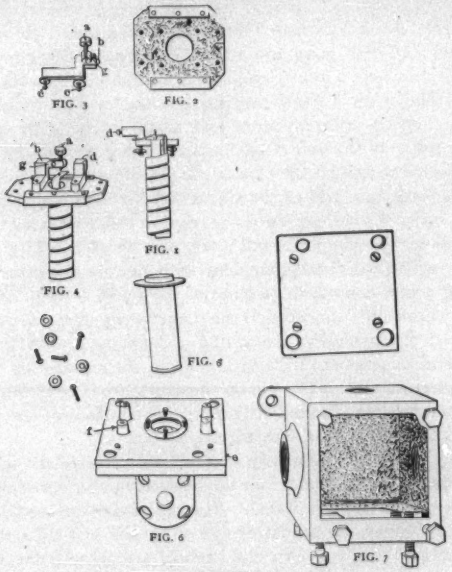


FIG. 8.—Conduit Thermostat, Type "A."

The top of the tube is flanged and is made water-tight by the rubber gasket *e*, Fig. 6, being secured by four screws. The mica plate with the spiral and terminals assembled thereon is fastened by four screws with washers to four studs *f*, Fig. 6, the spiral extending down into the water-tight tube.

To adjust, the working parts are taken from the box, Fig. 7, so as to be readily assembled. The proper electrical connections having been made (bell and battery in series with *b* and *d*,

Fig. 4), the water-tight tube, Fig. 5, containing the spiral, is placed in water as deep as possible, without allowing the water to run over the top of the tube. The water is then heated and the rise of temperature is as follows:

80° to 100° F. 5 minutes.
100° to 110° F. 10 "

When the temperature has reached the latter limit, the adjusting screw is run down until the circuit is closed and the bell rings. The fixture is made heavy with strong gear to resist mechanical injury.

General Alarm System.—This consists of a board on which is mounted a 12-inch gong and a brass case containing clockwork. The case contains a heavy coil spring which will give the alarm twice. The drum of the spring is connected by a gear wheel to a spindle carrying upon its outer end a star-wheel with an anti-friction roller at the end of each star. These projections of the star-wheel take against the face of a lug attached to the lower end of the bell-clapper, and as the star wheel revolves counter clockwise, it raises the clapper until the friction roller releases the lug, which allows the clapper to fall by its own weight and by the aid of a spring. Two electro-magnets with double armatures, one carrying a pin, control the release of the main spring. A train of gear wheels are connected to the main spring drive, controlling the speed of unwinding the spring. Connected with the gear wheel is an escapement disk with holes in the surface for the pin of an armature arm. The pin on the armature is controlled by a double armature designed to prevent the release of the pin by the shock of gun fire, or otherwise.

The action of the mechanism is as follows: The electro-magnets with connections to line attract the horizontal and vertical armatures when the circuit is closed. The top of the horizontal armature takes under the adjusting screw on the end of a vertical armature and thus prevents the vertical armature from moving toward the magnets until the top of the horizontal magnet is driven in to clear the screw. When the vertical armature is attracted to the magnets, the pin taking the escapement disk is driven clear. Through the train of gear wheels, the main spring is then released and continues to revolve the star wheel, sounding the alarm for thirty seconds, or until the pin again falls into a slot in the escapement disk.

The contact-makers are usually located in the conning tower or the captain's stateroom, and from these points the entire sys-

tem of gongs may be put in operation. The contact-maker consists in general of a water-tight box containing a hard-rubber base upon which are secured six contact sections, separated from each other. A spider carrying switch lever is also secured to the hard rubber base on the under side. A metal spring on the spindle of the switch keeps it away from the contact sections and thus leaves the circuit open. The gongs are on battery circuits in multiple.

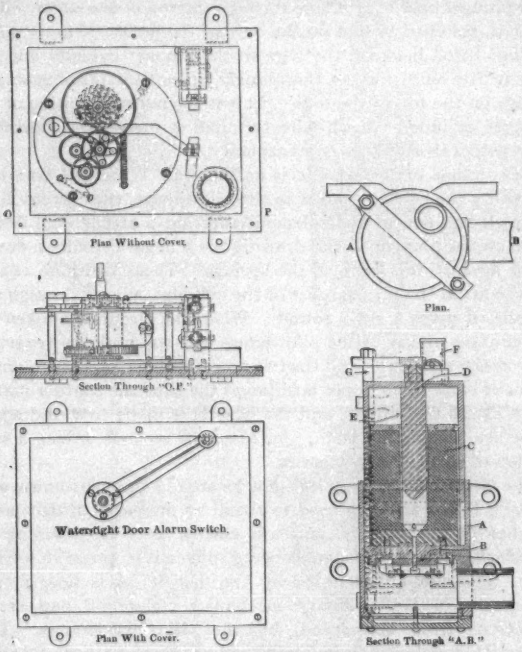


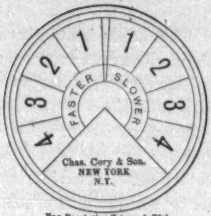
FIG. 9.

Solenoid Whistle.—These whistles, one of which is shown in Fig. 9, are used as a signal for closing water-tight doors, and consist of a contact-maker, which is usually placed in the pilot house, and solenoid whistles located throughout the ship. The whistle consists of a brass case, A, forming the chamber for wire terminals, space for the conduit terminal, outer cylinder of appar-

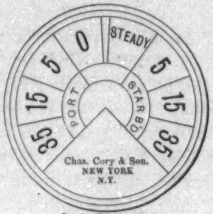
atus and lugs for securing the whole to the bulkhead. An insulated base, B, secured to the brass case carries a coil, C, incased in a brass cylinder, with hollow center about 1 inch in diameter. The plunger coil, D, forming an air chamber above the solenoid, is of iron, being an inverted hollow cylinder fitting closely over the outside of the coil and inside the brass case A. It is closed at the top and carries the armature plunger, E, of iron projecting downward into the solenoid. A shrill whistle, F, is mounted on this plunger case over a hole through the top of the cover. Two rods, G, fastened to lugs on the base of the brass coil carry spiral springs fitted between the lugs on the plunger cylinder and the lugs in the base, forcing the plunger up until it takes against a bridge on the top of the rods. This is the normal position of the plunger cylinder. Each wire terminal is fused on a porcelain base with a fuse of 3 amperes capacity.

The action of the whistle is as follows: When the circuit is closed by the contact-maker in the pilot-house, the current flows through the coil of the solenoid, exerting a strong pull downward on the plunger E, and drawing the plunger cylinder D downward against the force of the springs. There being no escape for the air in the air chamber of the cylinder, except through the whistle, it gives a shrill sound. When the circuit is broken by the contact-maker in the pilot-house, the coil no longer exerts a pull on the armature, and the two spiral springs force the plunger cylinder back to its upper position at the time the contact-maker again closes the circuit, and the whistle is made to sound again as before, this action lasting for about 35 seconds, giving a succession of shrill, sharp whistles.

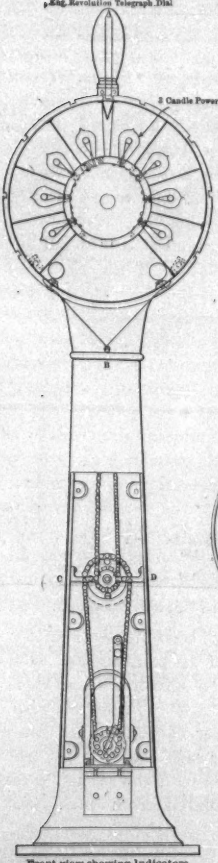
The electrical engine-telegraphs located in the pilot-house and conning tower are only used to signal an increased or decreased number of revolutions, and are chiefly used in steaming in squadron, the range of signals being sufficient to preserve formation. The speed designated by the flag officer is telegraphed by means of the ordinary mechanical telegraph and small variations from the speed, by the electrical devices. The transmitter includes an indicator and consists of a pedestal with a cylindrical case mounted thereon, containing the mechanism for ringing a magneto-bell at the indicator station and making an electric light burn behind a figure on the dial of the indicator. [See Figs. 10 and 11.] The form of a transmitter and its operating handles and clutch resemble the mechanical engine-room telegraph. On the spindle of the operating handle is a metal wheel



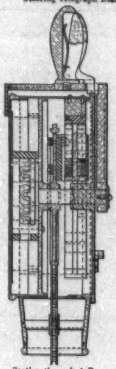
Eng. Revolution Telegraph Dial



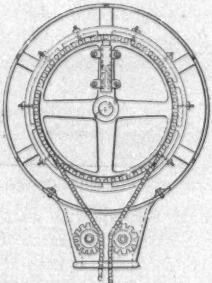
Steering Telegraph Dial



Front view showing Indicators



Section through A-B



Back view showing Contact

Multiplying Gear on line C-D

FIG. 10.

geared to fit on a sprocket chain. This chain leads down into a pedestal to a multiplying gear, and thence another sprocket chain leads to an armature of a magneto-generator secured in the pedestal. Wires are led from the brushes of this magneto-generator to the magneto-bell in the engine-room. Fastened to the sprocket-wheel of the transmitter on the after side is a contact-maker insulated from the wheel. It carries a pair of earbons, each pressed outward by a spring in the base. The

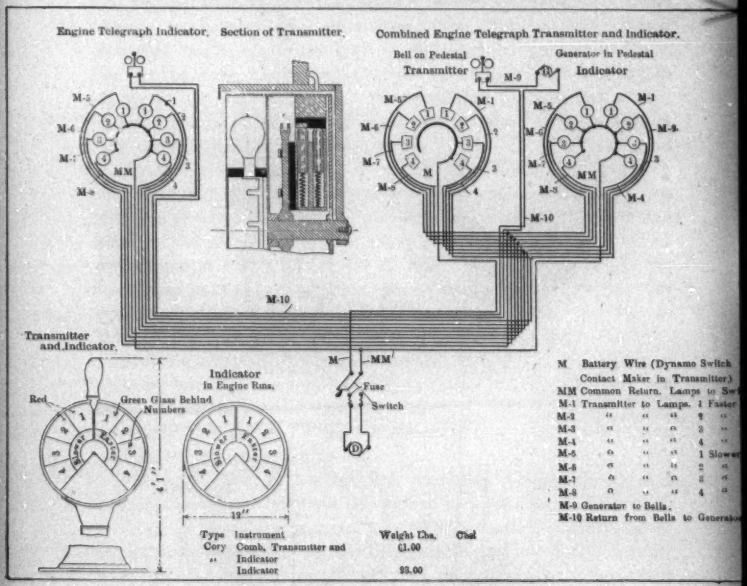

Engine Telegraph Indicator.
Section of Transmitter.
Combined Engine Telegraph Transmitter and Indicator.
Bell on Pedestal
Transmitter
Generator in Pedestal
Indicator
M-10
Transmitter and Indicator.
Indicator in Engine Rms.
Red
Green Glass Behind Numbers
Fuse
Switch
M Battery Wire (Dynamo Switch Contact Maker in Transmitter)
MM Common Return, Lamps to Sw
M-1 Transmitter to Lamps. 1 Faster
M-2 " " " 2 "
M-3 " " " 3 "
M-4 " " " 4 "
M-5 " " " 1 Slower
M-6 " " " 2 "
M-7 " " " 3 "
M-8 " " " 4 "
M-9 Generator to Bells.
M-10 Return from Bells to Generator
Type Instrument Weight Lbs. Cost
Cory Comb, Transmitter and $1.00
" Indicator
Indicator $3.00

FIG. 11.—Electric Engine Telegraph.

carbons make contact with metal sections secured to a circular hard-rubber base on the frame of the transmitter. One of these sections, connected to a common return wire, extends around the face of the instrument and is always in contact with the contact nearest the fuse. The other carbon makes contact with separate strips of metal, one for each order on the transmitter, which metal strips are connected with the section wires leading to the indicator and are insulated from each other. The

path of the current through the contact-maker when the pointer of the operating handle is over an order on the dial, is from the section wire contact into one carbon, through the metal socket, through the other carbon into the common return contact and out again to the line. A green glass is behind the numbers on the left side, which indicate slower speed. Sockets for the lamps are fitted to a hard-rubber base, and the connections to the wire are made in the center. Each lamp is connected to a common return and to that section wire which connects with a compounding contact in the transmitter. Each lamp is in a separate compartment, so that it can illuminate only one of the perforated numbers. The indicator in the engine-room is similar to the transmitter in all respects, with a magneto-bell placed above it. The figure shows the scheme of wiring, the current being taken directly from the main switchboard at normal potential. The magneto-bell on the indicator in each engine-room is wired in series with the transmitter in the conning tower and the pilot-house. A special arrangement is necessary on the transfer switch in the conning tower to bridge over the bell-circuits and not open the circuit. There is a transfer switch in the conning tower to cut out the pilot-house instruments when using those in conning tower.

Steering Telegraphs.—These are used to signal the desired degree of helm from the conning tower and the pilot-house to all steering stations. Combined transmitters and indicators are located in the conning tower and the pilot-house. Indicators are placed in the communication room, hand-steering stations on the upper decks and steering engine-rooms. These devices are exactly similar to the engine-telegraphs described above, except the orders on the dial.

Helm-angle Indicators.—These instruments, shown in Figs. 12 and 13, are installed at all steering stations, and indicate simultaneously the rudder angle at these stations. They are similar to the engine telegraphs, except the marking on the dials. The transmitter is located in the tiller room, the contact-maker, or arc, being secured on the rudder-head. The transmitter consists of a base of vulcanized rubber in the form of an arc, fastened to an iron bracket, carried on one of the protective deck beams. Upon the base are fastened fifteen strips of brass of varying widths, the center line of the strips being at angles, 0°, 2½°, 5°, 7½°, 10°, 15°, 25° and 35°, with the center line of the ship. These straps are insulated from each other by narrow sections of slate'

the whole forming an arc of 60°. On the inner side of this line of fifteen contacts and close to it, is a continuous strip of brass extending over the same length of arc. The contact-maker con- the section straps and the common return strap by spiral springs

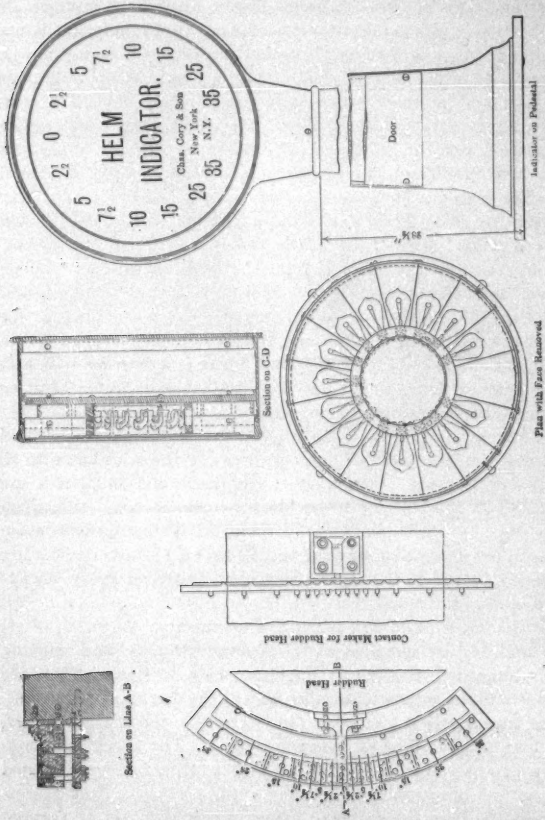


FIG. 12.

sists of a brass wire secured to the rudder-head, but insulated from it by hard rubber. Two holes bored in the ends of the arm carry the carbon contacts. These are forced downward against above the carbon, completing the circuit between the common

return and the section straps. Each section strap is connected to the lamp in each indicator, corresponding with the angle at which the section strap is placed. Then, if the rudder is hard to port, the helm hard to starboard and the connection is made between the common return strap and the section strap through the carbons, the light in all indicators will burn 35° to starboard.

Revolution and Direction Indicators.—These indicators, shown in Figs. 14 and 15, are located in the pilot-house and con-

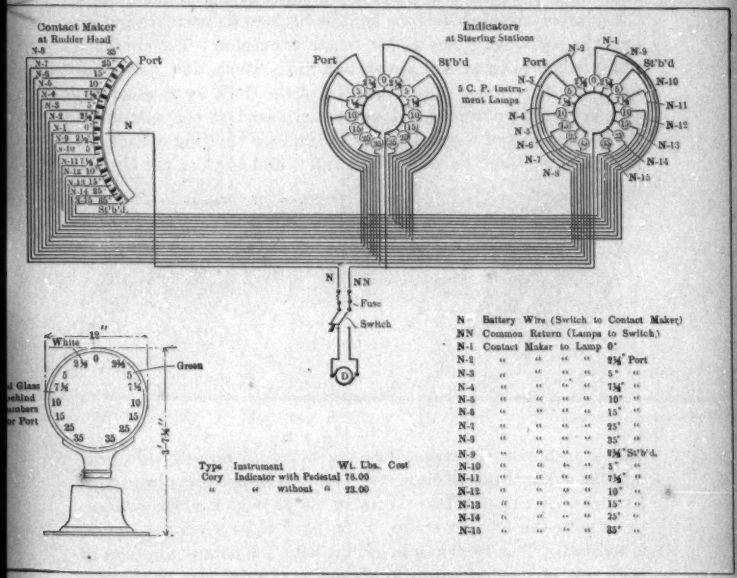

Contact Maker at Rudder Head
Port
N
Indicators at Steering Stations
Port
St'b'd
Port
St'b'd
5 C. P. instrument Lamps
N
NN
Fuse
Switch
White
Green
12"
3'-7¼"
Type Instrument Wt. Lbs. Cost
Cory Indicator with Pedestal 76.00
" " without " 23.00
N Battery Wire (Switch to Contact Maker)
NN Common Return (Lamps to Switch)
N-1 Contact Maker to Lamp 0°
N-2 " " " " 2½° Port
N-3 " " " " 5° "
N-4 " " " " 7½° "
N-5 " " " " 10° "
N-6 " " " " 15° "
N-7 " " " " 25° "
N-8 " " " " 35° "
N-9 " " " " 2½° St'b'd.
N-10 " " " " 5° "
N-11 " " " " 7½° "
N-12 " " " " 10° "
N-13 " " " " 15° "
N-14 " " " " 25° "
N-15 " " " " 35° "

FIG. 13.—Helm Angle Indicator.

ning tower, one for each engine. The indicator consists of a circular water-tight case with glass face. The enamel dial is marked "ahead" and "astern" just over two small pointers. [Fig. 1.] Two sets of double-pole electro-magnets, A [Fig. 2], are mounted on the back of the case, one set for ahead and one set for astern. The figure shows the upper magnets only. Each set of magnets has an armature, B, pivoted on a vertical lug at the side of the coil, C. The end of the armature takes against

the side of a vertical spindle, D, which carries a pointer at the end. A score, or flat recess, is cut in the round spindle where the armature bears against it, which score lies against, and at an angle of 45° to the armature. When the armature is attracted to the magnets the end is driven against the spindle and turns it until the screw is flat against the armature, thus turning the spindle and the pointer at its end through an angle of 45°. When the circuit in the electro-magnet is broken, the magnets cease to attract the armature, and a spiral spring at the base of the pointer-spindle levels the spindle back to its normal position and the score again lies at 45° to the armature. The circuit is made and broken at each revolution of the shaft, and it depends upon the direction of the revolution of the shaft as to which set of magnets is energized. A switch is placed at the bottom of the indicator, and a spiral spring in the base to bring it back to mid-position when twisted to the right, and to close the circuit.

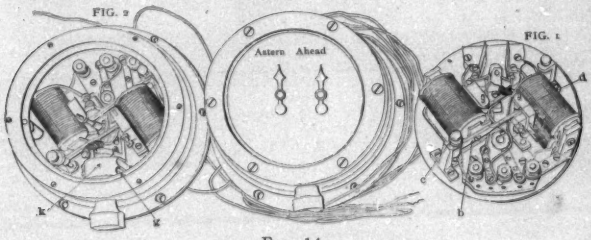


FIG. 14.

Two upright contact-strips of metal, G [Fig. 2], on each side, bear against a hard-rubber ring, K. Inserted longitudinally in this hard-rubber ring are two pieces of metal, which make connections with the upright strips, G, on both sides when the switch is twisted. This switch is in circuit with the common return of both sets of magnet wires, as shown in the diagram of connections [Fig. 5]. A lamp is installed in the indicator and illuminates the dial.

The contact-makers on the main shaft shown in Fig. 15, are located in the shaft alleys. An iron bracket in the bulkhead supports a hard-rubber base, A [Fig. 3]. A vertical sliding rod, B, is attached to the base and is in electrical connection with one wire of the common return. On the lower end of the sliding rod, a small gear wheel, C, is carried, gearing into a band, D, [Fig. 4], which is secured on the main shaft, being eccentric to the shaft

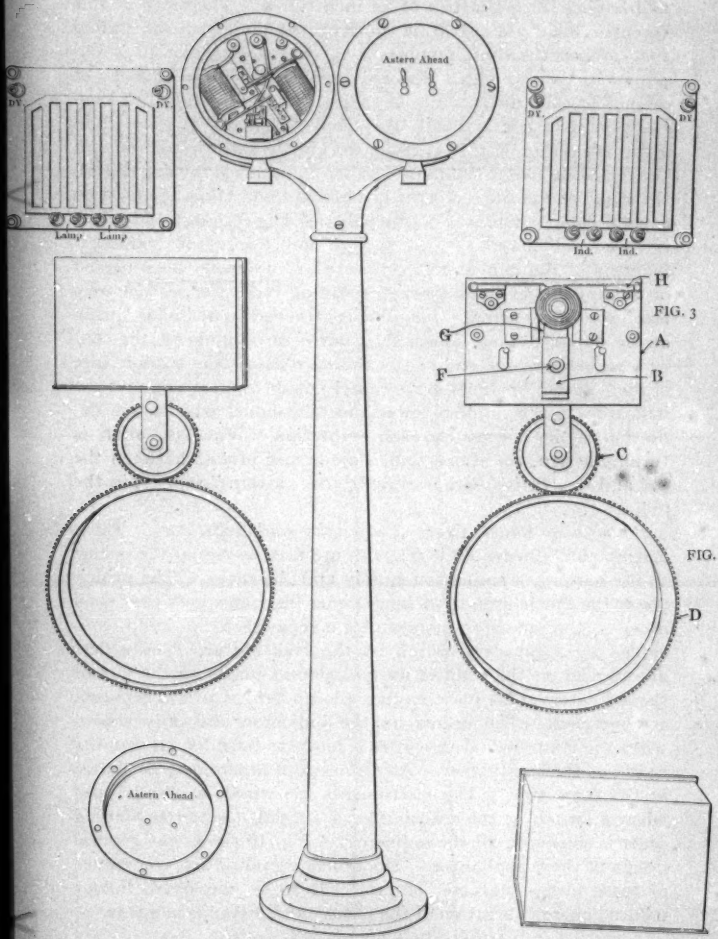


FIG. 3

FIG. 4

FIG. 15.

and having three-quarters of an inch throw. The teeth of this eccentric band are cut to fit those on the pinion on the sliding rod. When the shaft revolves a vertical sliding motion is imparted to the rod which is raised and lowered three-quarters of an inch at each revolution. A special spring is installed to keep the pinion in contact with the band. The rod is pivoted in about the center, F, the pivot pin working in a slot in the rod and the top being free to oscillate. When the shaft is turning ahead, the upper end of the rod is thrown inboard and takes against two small rollers, G, mounted on the base, avoiding friction as the rod is raised and lowered. One section wire leading to " ahead " magnets of the indicator is connected to a spring, H, mounted on a hard-rubber base above the sliding rod; the section wire leading to the " astern " magnets is attached to a similar spring on the opposite side. When the shaft is turning ahead, the connection between the end of the sliding rod and the section wire of the " ahead " magnet is alternately made and broken, and the indicators in the conning tower and pilot-house will show a deflection of the pointer for each revolution. When the shaft is turning astern, the connection is made and broken between the rod and the section wire leading to the " astern " magnet in the indicator.

Battle and Range Order Telegraphs and Indicators. These instruments, illustrated in Fig. 16, are used to signal the orders to the battery, ammunition supply and the range. The principle of the battle-order and range-order instruments is that each order on the indicator is shown by a separate 5 c.p. lamp, controlled by a separate switch on the transmitter. The orders are marked on the counter by transparent plates on the face of the indicators, each plate having a lamp behind it in a separate compartment. The orders on the indicators are only shown when the lamp behind the order is made to burn by turning the switch of the transmitter. Any number of orders may be shown at the same time. The instruments are wired in parallel and when a switch of the transmitter is turned, the corresponding order is shown on all the indicators. Fig. 16 shows the general design of these appliances. The orders signalled are, commence or cease firing, character of projectile to be employed, full or reduced charge, direction of the enemy and distance in yards.

Ardois Signalling System.

The object of the night signaling set, shown in Figs. 17 and 18, is to transmit rapidly and accurately under suitable condi-

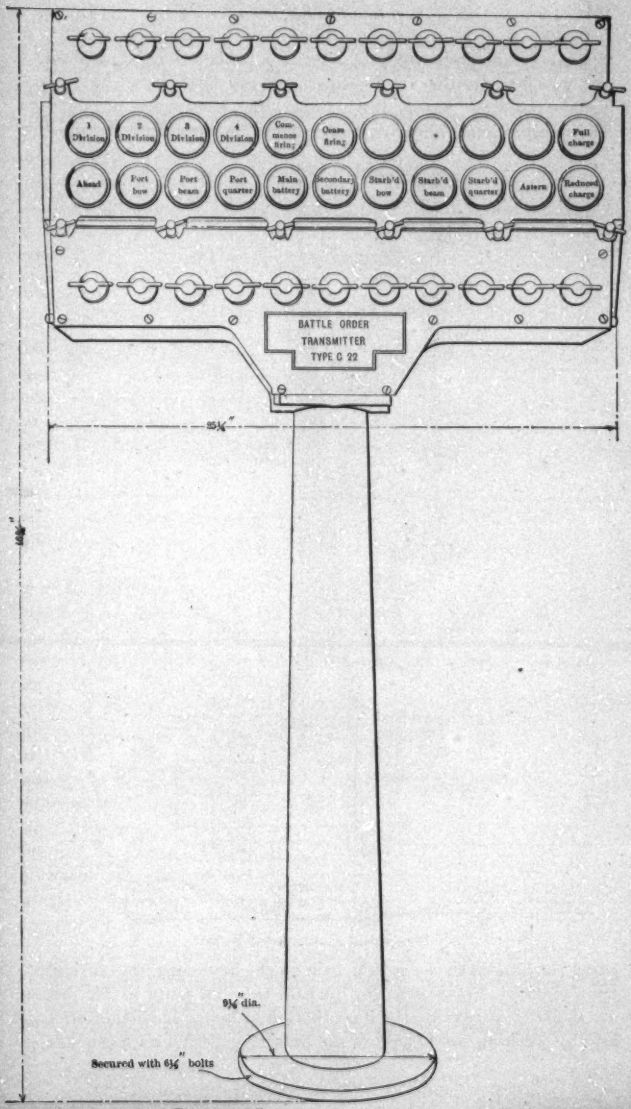


FIG. 16.—Battle Order Transmitter.

tions, a pre-arranged code of signals to a distant point, as from one vessel to another, or for squadron and fleet tactics, and for signals between vessels and co-operating commands on shore. The method is as follows: With current on the circuit, by oper-

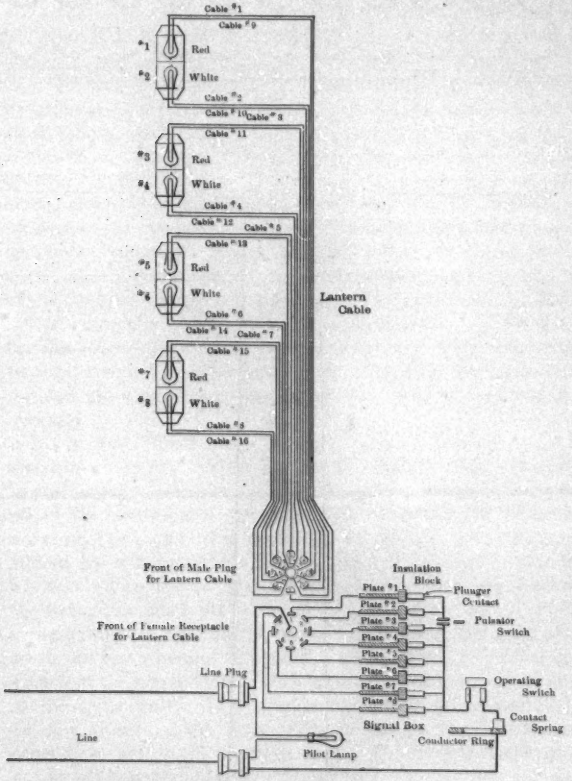


FIG. 17.—Hand Control Projectors.

ating the handle of the switch lock on the keyboard, the various combinations represented by dots on the dial plate in Fig. 19, are made to appear by the illumination of lamps in the lanterns, and by working the handle of the pulsating switch on top of the

spindle, the lights in the upper lantern are pulsated. The set consists of four double lanterns with lamps, a ladder, cable and keyboard. Each of the four lanterns shown in Fig. 18 has two compartments; the upper one has a red lens, the lower one a

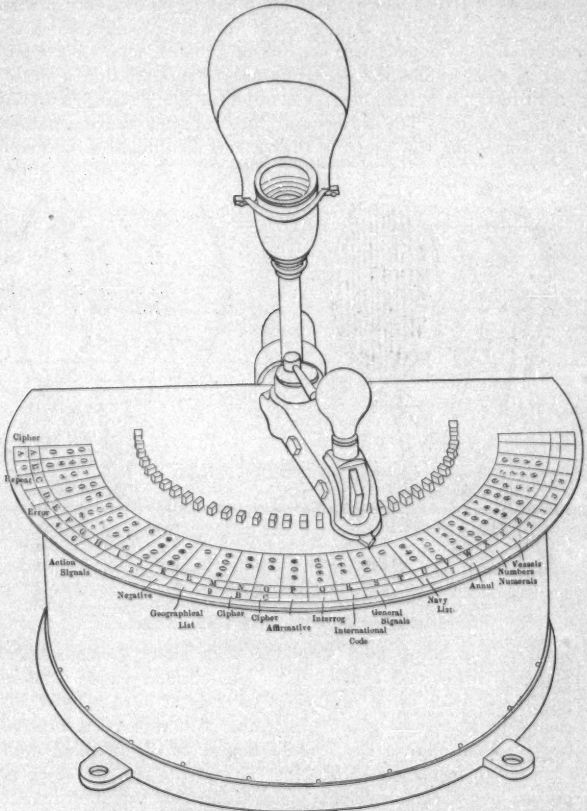


FIG. 18.—Connections for Signal Set Form "E."

white lens. The wires from the cable pass through stuffing boxes in the center of the caps, which screw on each end of the lantern and make it watertight by a gasket. Each cap is fitted

with a socket and a standard 32 c.p. lamp. The ladder is made of galvanized iron wire. One end of the ladder is made fast to an outrigger, or short gaff, near the masthead and the other end is secured to a turnbuckle fastened to the deck. The cable consists of 16 conductors, each lamp having its own return wire. The wires connect to a plug which fits into a receptacle on the keyboard. The keyboard consists of a dial, handle for the pulsating switch, and the operating handle mounted on a water-tight box. It is illumined by a standard 32 c.p. lamp, supplied with a shade. The water-tight box contains the mechanism for connecting the lamps in the various combinations and con-

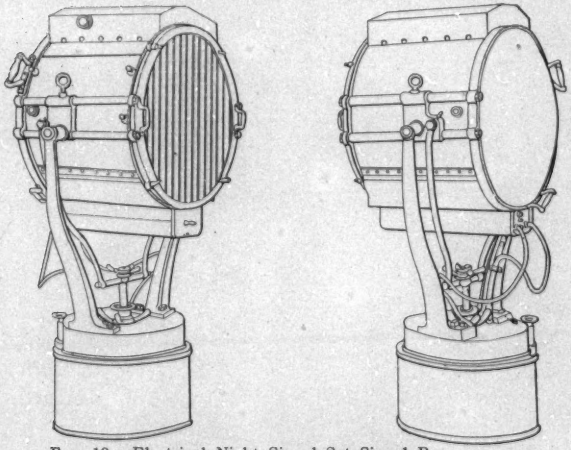


FIG. 19.—Electrical Night Signal Set Signal Box.

sists of a rotating stud provided with eight spring-contact plungers, which rest against eight semi-circular plates. These plates are made up of insulating sections of hard rubber and composition, each of which is in connection with its respective lamp. When one of the contact fingers of the rotating stud rests on an insulating section, the circuit through the lamp is broken, but when it rests on a metal section, the circuit is closed. When the pointer is turned to the position on the dial corresponding with the desired signal, some contact plungers rest on the hard-rubber section and others on the metal section, thus connecting into circuit the desired combination of lamps.

Searchlights.

Searchlights, Fig. 19, consist of a fixed pedestal, or base, surmounted by a turntable, carrying the drum in which are contained the lamp and the mirror. The base contains the electric connections and is arranged for bolting direct to the deck and platform. The turntable is free to revolve indefinitely in either direction in a horizontal plane, and may be clamped rigidly in any position, Fig. 20. The drum is trunnioned on two arms bolted to the turntable, and has a vertical train of 70° above horizontal and 30° below. This drum may likewise be clamped in any intermediate position. Parabolic mirrors are now used and are of highly polished glass,

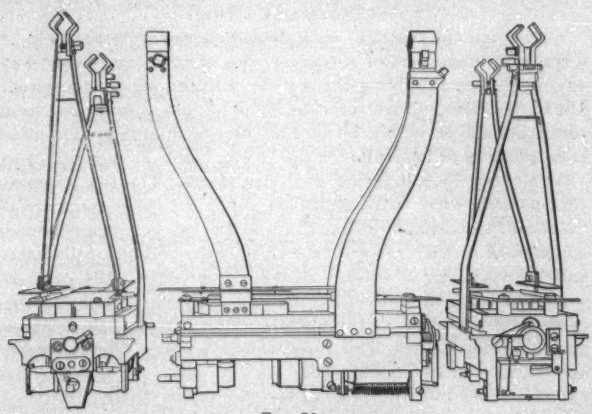


Fig. 20.

silvered on the back. The mirror is mounted in a separate metal frame, lined with non-conducting material in such a manner as to allow for expansion due to heat, and to prevent injury from concussion. The lamp is of the horizontal carbon type, designed for both hand and automatic control. It will burn for six hours without renewing carbons. The front of the drum contains a door of plain glass strips and a shutter for use in signalling. Until recently, the projectors were fitted with a system of electrical control for training the beam of light, but at present hand control is exclusively installed. The intensity of the beam of light is required to be such that on a clear, dark night a light-colored object 10 by 20 feet in size will be plainly discernible at

a distance of not less than 4,000 yards for the 18-inch projector, 5,000 yards for the 24-inch projector and 6,000 yards for the 30-inch projector. The current required for operation with the voltage across the arc for the four standard sizes is:

13–inch,	18–20	amperes,	45–48 volts.
18 "	30–35	"	47–50 "
24 "	40–50	"	48–52 "
30 "	70–80	"	49–53 "

Smeltzer carbons are used extensively and give good satisfaction, the positive carbon in the larger sizes being corded, with the negative carbon solid and in some cases having a core smaller than that of the positive carbon.

Incandescent Lamps.

Under the old practice, incandescent lamps were not only of a special voltage, but of a special type of bulb, and delay was experienced in supplying the service with the number required. Under the new voltage recently adopted, 125 volts at machine terminals, the lamp will be of 123 volts, with an allowed variation from 122 to 124 volts for the 16 c.p. lamps, and from 121 to 125 volts for the submarine, or diving lamps. The 16 c.p. lamp, the one most used, will conform in shape with the commercial type, and thus enable its purchase in the market as a common commercial article. It will be seen that the voltage of the lamp and the variation in voltage allowed, from 122 to 124 volts, is consistent with the maximum allowed drop on the lighting circuits, and will admit of the installation of lamps at the voltage at which they deliver their rated candle power. The following are the standard lamps allowed: 16 c.p., clear and frosted; 32 c.p. clear, and 150 c.p. clear, in the case of the diving lamp, besides instrument lamps for special purposes of 1 and 5 c.p. The average efficiency of the 16 c.p. lamp is to be between 3.4 and 3.6 watts per candle power; for the 32 c.p. between 3.4 and 3.8 watts per candle, and for the 150 c.p. diving lamp between 2.9 and 3.3 watts per candle power. The life of an incandescent lamp is an important consideration in naval installation, as the ships are so frequently removed from a source of supply. It is proposed to specify 800 hours for the 16 c.p., 500 hours for the 32 c.p., and 300 hours for the 150 c.p. lamp as the average life, with the above efficiencies, the lamps not to have lost more than 20% of their rated candle power while burning for these periods at the rated candle power.

A paper presented at the 166th Meeting of the American Institute of Electrical Engineers, at New York, May 28th, 1902.

THE MILITARY CABLE SYSTEM OF THE PHILIPPINES.

BY CAPT. EDGAR RUSSEL, SIGNAL CORPS, U. S. ARMY.

After the progress of negotiations of the Commission at Paris in November, 1898, had made it certain that the retention of the Philippines would be recommended, steps were immediately taken by Gen. A. W. Greeley, the Chief Signal Officer of the army to provide for the inter-island communication which his forecast of coming conditions indicated would be necessary. With this in view, arrangements were made for the purchase of cable and the fitting out of a suitable ship for cable laying.

It should be stated that at this time there were no government cables in the Philippine archipelago, and but one commercial cable system, about 600 miles long, that of the Eastern Extension Telegraph Company, which connected Manila, Luzon, with Iloilo, Panay; Bacalod, Negros; and Cebu, Cebu. There were no Spanish land lines except on the island of Luzon, and these falling into the hands of the insurgents in a deteriorated condition, went to pieces and required replacement by the Signal Corps. It may thus be said that no telegraph system existed in the islands, apart from the single commercial cable system mentioned above.

As soon as the treaty of peace had been ratified, in February, 1899, the contract was let for the manufacture of 212 miles of cable and the army transport *Hooker* was fitted out as a cable ship. The supervision of all matters connected with the manufacture, loading and subsequent care of the cable was entrusted to a Signal Corps officer, Major Joseph E. Maxfield.

The *Hooker* arrived at Manila in July, 1899, but cable laying being delayed, she was sent by the Quartermaster's Department

to Hong-Kong, and on her way out of Manila Bay was wrecked. By the most strenuous efforts of the signal officers all the cable machinery and instruments and most of the cable were taken off. A few months later the Signal Corps made its first essay in deep-sea cable laying in the Philippines. The cable machinery and the cable from the *Hooker* were put on a small coasting steamer chartered at Manila, and in the autumn of 1899, two lines of cable were laid, one connecting the islands of Leyte and Cebu, and the other the towns of Pasacao and Guinayangan on the west coast of Luzon. The subsequent use made of these cables and their great importance in the general scheme of communication have fully justified the original venture and emphasized the excellent work done in overcoming the obstacles presented by the wrecking of the *Hooker*.

The rapid spread of the American occupation in the southern islands of the archipelago soon made further provision necessary, and in the spring of 1900 active preparations were made for further extension of the cables. Seeing that a long period of cable laying was in prospect, Gen. Greeley, the Chief Signal Officer of the army, requested that a transport be assigned for that purpose. The transport *Burnside* was selected, thoroughly overhauled and refitted for use as a cable ship. Three cable tanks were put in, a testing room was built, and the forward deck was prepared for the placing of cable machinery as soon as the vessel arrived at Manila. Five hundred and fifty-three miles of deep-sea cable and eight miles of shore end were put aboard in New York. The *Burnside* arrived at Manila early in December, 1900, and was immediately fitted with the cable machinery originally sent out with the *Hooker*.

As this was the first deep-sea cable laying ever done by a ship regularly fitted out for that purpose by this Government, it may be interesting to describe personnel and material somewhat fully. The Chief Signal Officer of the Division of the Philippines Lieut.-Col. James Allen, Signal Corps, afterward Brigadier-General of Volunteers, was in charge of cable operations. He was assisted by a staff of five signal officers, Captains George O. Squiers and Edgar Russel and Lieutenants Henry S. Hathaway, Frederick W. Jones and Earle W. Binkley and two civilian experts, Mr. T. A. Hamilton, cable electrician, who had had previous distinguished service with commercial companies, and Mr. Henry Winter, cable engineer, who had also had great experience in cable laying and repairing. Seven en-

listed men of the Signal Corps were regularly on board, a number of others being left as operators at various stations. Thirty-six natives were employed as laborers, their duties being mainly in the tanks during cable laying. The ship's officers and crew and the supply departments were under charge of an officer of the Quartermaster's Department, Major J. C. W. Brooks. The division of technical duties among the officers on board was made at once, although all took turns at watch at various important points when cable laying was in progress. As the duties were new to most of the officers and men, no opportunity for drill and instruction was lost, and, when once started, the work being almost incessant, great progress was made in a surprisingly short time.

The take-up gear used was made in New York. The cable coming up from the main tank through a bell mouth over the center passed over a fair lead, or sheave, and thence three or four times around the drum of the take-up gear, then through the dynamometer, and finally over either the bow or stern sheaves, circumstances determining whether cable should be laid over bow or stern. The testing room was fitted with an excellent assortment of instruments. Standard bridges, condensers, shunt-boxes, discharge and reversing keys, excellent galvanometers of the Sullivan and Thompson marine patterns and testing batteries were provided. The high insulation leads to the cable tanks were brought into the testing room in a secure and convenient way. The lower ends were fastened in boxes near the tanks, the terminals being kept dry by an electric lamp in each box.

During cable laying an officer was constantly on the bridge taking locations by sextant or compass observations every fifteen minutes. Another officer was in the cable tanks incessantly, watching the native laborers. He was provided with an electric signal for "full speed astern" in case a kink or snarl started up out of the tank, beyond control of the helpers. Another took general supervision of the machinery, seeing that proper amounts of water were used, and that all sheaves were kept oiled, the dynamometer closely observed, etc. The methods of getting the cable end ashore depended entirely on the peculiarities of the landing. Usually small boats in tandem, supporting the cable at intervals, were hauled shoreward by a rope running from the leading boat to a sheave secured on the beach, and thence back to a steam winch on the ship. Meantime while

the shore end was being landed and trenched up to the office, or cable hut, the officer in charge of the office installation was engaged in constructing shelves and tables and setting up batteries and instruments.

Many of the Philippine cable stations were shared by soldiers of the garrison. In few cases was the white population other than military, and in some stations the cables were laid at a time when the sound of firing was a not infrequent accompaniment to the click of the office instruments. Many of the routes over which cables were laid were very imperfectly charted. In laying the cable from Iligan to Misamis, for example, along northern Mindanao an error of over five miles in a charted distance of twenty-five miles was discovered. This, taken in conjunction with numerous unchartered rocks and shoals and the absence of any shore lights, made navigation especially hazardous.

Owing to this uncertainty, and the meagreness or absence of soundings, it was necessary to precede each stretch of cable laying with a line of soundings. The Sigsbee sounding machine, utilizing piano wire and an iron detachable sinker, was used. The deepest soundings obtained were south of Mindanao when the line went down over 1200 fathoms. The heavy iron sinker failing to be detached, was brought up ice cold from this depth by the rapid little take-up gear attached to the sounding machine, an interesting exemplification of the fact that deep-sea temperatures are alike in torrid and frigid zones.

The first stretch of cable laid was that connecting Dumaguete, on the island of Negros, with Misamis, on the north coast of Mindanao, 98 nautical miles. All went well during the first 30 miles of laying, when a sudden "foul flake" appeared, carrying a mass of tangled cable up to the cable machinery and blocking it; although "full speed astern" was instantly signalled, the officer on watch sorrowfully noted the steady rise of the dynamometer until the 7000 lb. mark was reached, when the cable snapped and the end went overboard. Soundings were quickly taken and a mark buoy was soon placed. Four hundred fathoms was the depth at this point. The ship then went back about a mile, the grappling gear was lowered and slow dragging across our course was begun. The cable was soon caught, as indicated by the dynamometer, carefully raised, the bight cut and the end brought on deck. A test showed "all right," communication with the men on watch in the cable hut at Misamis

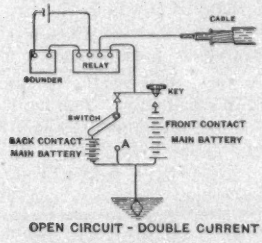
being at once obtained. The splicing experts proceeded to splice the end to that of the cable in the main tank, the splice was lowered, and seven hours after the accident we were again under way, completing the laying of the cable without other incident. No accident exactly similar to this occurred in laying subsequent cables, but every other accident known to the profession did occur. Even an earthquake with a subaqueous landslide as a cable destroyer was provided for our especial benefit. So, instruction to the inexperienced was thorough, for thanks to a very capable cable engineer and the keen interest and hearty coöperation of all, every difficulty was successfully overcome.

On these lonely coasts many expedients were resorted to where difficult landings had to be made or cables were to be laid in shallow waters. One of these cases was the laying of a cable from Misamis south about 20 miles into Panguil Bay, a shallow body of water which nearly cuts the island of Mindanao in two at this place. The ship could not get any further than Misamis, so two native boats, called bancas, were hired, and the boats and outriggers were floored over. Cable was coiled on these, and taken up the bay and river by the ship's launches. The landing was at a deserted place in the Moro country called Lintogup. Here a cable hut was built, and, after many tribulations, the cable was laid back to Misamis, only to find that a fault had developed at the other end during the laying. Another weary repair journey across the treacherous wind-swept shallows had to be made. A land line connects the lonely hut at Lintogup with the cable station Tucuranon the south side of the Mindanao isthmus. From this point the cable goes to Zamboango.

Another coast cable has recently been laid connecting Tucuran with Malabang and Parang Parang. This is the country of the Moro savages, whom our soldiers have been compelled to chastise because of their failure to make restitution for robbery and the murder of Americans. The incalculable saving of time made by this complete system of cables connecting these places on Mindanao with Department Headquarters at Cebu and District Headquarters at Zamboango would be hard to estimate. Owing to the great distance from Manila, the supply departments would otherwise scarcely have been able to cope with the sudden demands made on them.

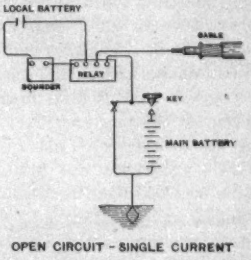
In the cable stations two methods of open-circuit Morse working were used,—the single and double current methods. In

both, polarized relays were employed. An inspection of the diagrams (Figs. 1 and 2) shows the methods of connecting up. In only one of the cables, where the length was over 150 miles, was it found that the "k.r." was sufficient to make any troublesome drag in sending at moderate speeds by the single current method. At first the ordinary telegraph switchboards were used, but whenever testing had to be done the imperfect insulation given by these switchboards made the operations of "earthing," "freeing" and "cutting through" somewhat unreliable. Another form of switchboard for small stations has been devised. It is shown in the illustration (Fig. 3). It consists of a hard-rubber base on which are placed the ordinary straps, buttons and binding posts for a two-wire board. In addition two revolving slotted copper strips are shown for making connections, placing the cable to "instruments," "earth" or



OPEN CIRCUIT - DOUBLE CURRENT

FIG. 1.



OPEN CIRCUIT - SINGLE CURRENT

FIG. 2

"free." The whole is fitted with a glass door and wooden cover of sufficient depth to admit placing a small cup of desiccating material within, when cable testing is going on.

In double current working a separate switch is needed in connection with the open circuit key to cut out the "back contact" battery when through working. This gives trouble to the operator accustomed to the ordinary switch lever, and the key illustrated was devised to overcome this difficulty. As will be seen, by altering the connections of the legs, the key may be used for either ordinary closed circuit, single, or double current open circuit. (Fig. 4). The ordinary sal-ammoniac batteries were used. It was found that very satisfactory service with the Stroh or Western Union form of polarized relay adopted, could be obtained with 15-milli-amperes, and the amount of battery was adapted to that strength of current. It was soon found in

the Philippines that in no telegraph office could the ordinary office wire be depended upon. Consequently nothing but rubber-covered wire was permitted to be used in the cable offices, even on the local circuits.

These apparently trifling matters made much trouble until they

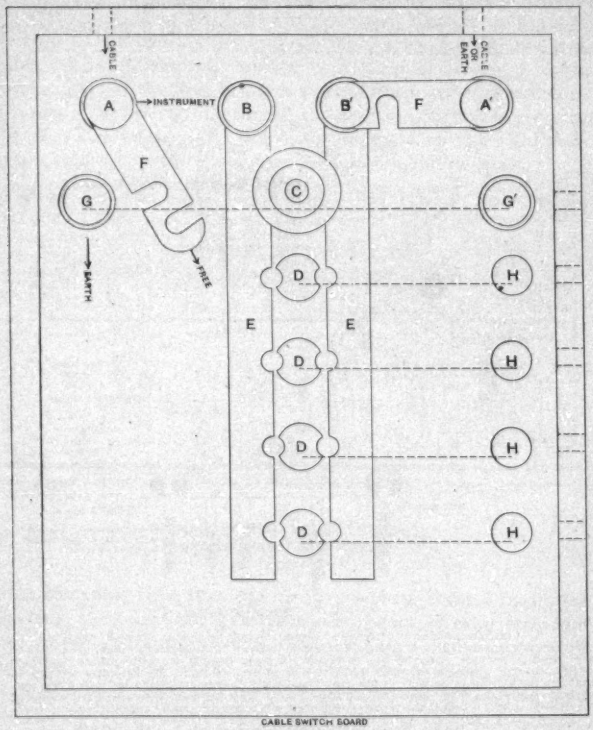


FIG 3.

were remedied. The great humidity and continuous high temperature produce remarkably rapid deterioration of all office material, and, it may be added, of the operators and officers as well. As it was desired in some instances to link a number of the local cables for through working, the open circuit repeater

sets were devised. The wiring diagram and general design of one of the table sets are given in the illustrations. The complete instruments are mounted securely on telegraph tables, and the binding posts for attachment to the batteries and lines are plainly marked. The double switch in the center of the table provides changes of connections for independent working of the lines, or for repeating. In Fig. 5 and Fig. 6 are shown the wiring diagram and table top respectively.

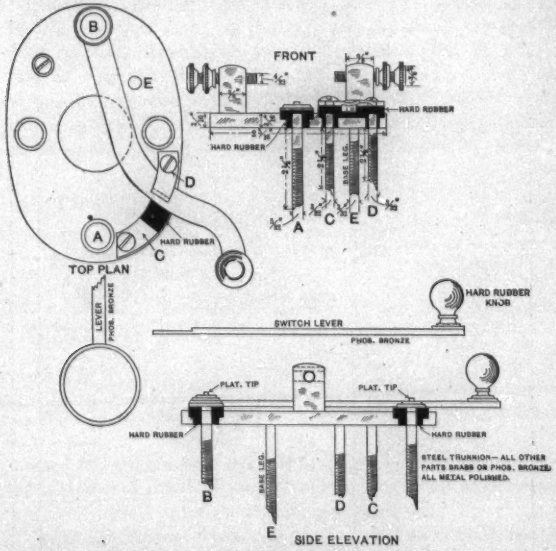


FIG. 4.—Combination key for open or closed circuit (single or double current). With relay connected to E, one pole of main battery to A, earth to C, and one pole of back contact battery to D, the key is suited for open circuit working either single or double current. (Single current with switch closed to left. By opening switch to right the back contact battery is put into circuit for double-current sending). By connecting A and C together, and E and B together, it may be used as an ordinary closed circuit key, A and B being the points connected with line and relay respectively.

Duplex sets have been procured and sent to the Philippines (for use over the cables and land lines) in charge of a number of Signal Corps men, trained especially in working and installing them. The sections over which they are to work are as follows:

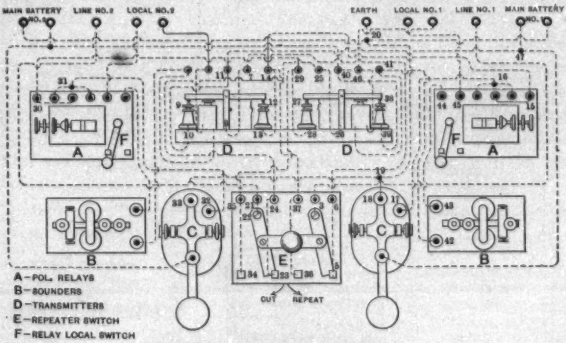
Manila-Guinayangan, 140 miles land line, polar duplex.

Guinayangan-Legaspi, 60 miles cable, 70 miles land line, differential duplex.

Legaspi-Calbayog, 157 miles cable, 10 miles land line, differential duplex.

Calbayog-Cebu, 140 miles cable, 35 miles land line, differential duplex.

These sections form an important line connecting Headquarters, Department of the Southern Philippines, at Cebu, with Headquarters, Division of the Philippines, at Manila. In the connecting lines there are 255 miles of land line, and 357 miles of cable. The differential duplex was adopted where a cable formed part of the line, in order to conform to open circuit conditions. The wiring diagram of the set for a station is given in Fig. 7. The instruments are ready mounted on two light telegraph tables, one for the sender and one for the receiver.



SIGNAL CORPS REPEATER SET.
SINGLE CURRENT OPEN CIRCUIT.

FIG 5.

At the same time that the men were being trained in duplex working, they were being instructed in the use of cable recorders and automatic transmitters. Sets of these instruments were procured from one of the best makers, and the men were constantly drilled in sending on the double key, in perforating tape for the automatic transmitter, and in reading the recorder tape. They had obtained a fair degree of proficiency in their eight-weeks' practice when they left for the Philippines. It is proposed to use these instruments over the new cable line between Batangas and Cebu direct. The sections between Marinduque, Romblon and Masbate islands are about to be laid. During most of the day it is proposed to work the line in sections by the

ordinary open-circuit Morse; and at certain hours the local offices will be cut out, the lines will be linked together, and the routine reports, personal and press messages and other through business between Manila and Cebu, rapidly exchanged by means of the automatic transmitters, the tape having been prepared for this as messages are filed for transmission at Cebu or Manila.

If it be asked why this method of working is proposed, it may be said that the military land lines and cables, to a large extent, take the place of the letter mail in official and in much personal business. The average message is about 30 words in length, and for many months 10,000 messages per day have been trans-

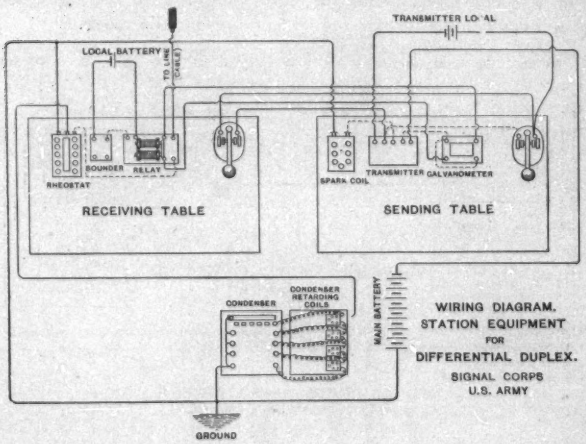


FIG. 6.

mitted over the Signal Corps line. It was ascertained by the Chief Signal Officer in the summer of 1901 that the average time required for sending letters from Manila to all telegraph offices on the Island of Luzon alone and getting replies, was about one month. It is proposed to try rapid telegraphy between Manila and Cebu to furnish some substitute for the slow mail communication. The local offices retain Morse working because it would not pay to put expensive and delicate instruments in each and train men to be experts to supply them.

Neither land lines nor cables were open, until quite recently, for commercial business and no statistics are at hand regarding

a period of sufficient length to admit of estimates. The rates as first established were as follows:

1. Messages transmitted between points on the same island, two cents per word.

2. Messages between points on different islands, four cents per word.

3. Press specials, half rates.

Address and signature counted; the minimum charge is for ten words.

All of the cable laid in the Philippines by the Signal Corps has rubber insulation. For the trying conditions under which much of it had to be transported, stored and laid, there is no question that the choice of rubber over gutta-percha was a wise one. For example, much of the cable brought over on the *Hooker* was necessarily exposed to the weather for months before it could be laid. In that tropical climate gutta-percha cables would have been reduced to worthless junk, but the rubber cables had in many instances several hundred megohms dielectric resistance per knot, out of the original one thousand. The rubber insulation when immersed to depths of over 900 fathoms showed steady improvement as it went down. Two kinds of deep-sea cables are in the system, the data concerning these being briefly as follows:

	A.	B
CONDUCTOR.	SEVEN NO. 24 COPPER.	SEVEN NO. 21 COPPER.
Diameter of Insulation.	8/32"	9/32"
Copper Resistance per knot	21.6 at 70° F.	9.7 at 60° F.
Dielectric " " "	1400 Meg. at 60° F.	750 Meg. at 75° F.
Capacity " "	.88 m.f.	.98 m.f.
Armor	16 No. 12 steel wires.	16 No. 10 steel wires.
Approx. weight per knot.	1.5 tons.	1.75 tons.

The core in each was taped, served with a double layer of jute, armored, then served with a double layer of jute and finished with a covering of compound and soapstone. The shore end cable was similarly made but received an additional armor of 18 No. 6 steel wires and another double layer of jute and compound. This shore end weighed about 6½ tons per knot.

The stations and distances in the cable system of the Philippines up to the present time, are given below:—

Laguna de Bay (Luzon)	Calamba-LosBanos	4	Miles
	Calamba-SantaCruz	18	"
	SantaCruz-Siniloan	9	"
Manila-Cavite, (Luzon)		8	"
Naic-Corregidor Island, (Luzon)		12	"
Guinayangan-Pasacao, (Luzon)		51	"

Legaspi-Bacon, (Luzon)	29	Miles
Sorsogon-Palanog (Masbate)	62	"
Batangas-Calapan (Mindoro)	30	"
Calapan-Boac (Marinduque)	45	"
Palanog-Calbayog (Samar)	75	"
Calbayog-Catbalogan (Samar)	37	"
Catbalogan-Carigara (Leyte)	45	"
Ormoc (Leyte)-Liloan (Cebu)	72	"
Liloan-Cebu) ?	13	"
Milagros (Masbate)-Capiz (Panay)	74	"
Argao (Cebu)-Loön (Bohol)	14	"
Maasin (Leyte)-Surigao (Mindanao)	56	"
Oslob (Cebu)-Dumaguete (Negros)	17	"
Dumaguete-Misamis (Mindanao)	115	"
Misamis-Lintogup, Mindanao (no station)	23	"
Misamis-Iligan (Mindanao)	32	"
Iligan-Cagayan (Mindanao)	60	"
Tucuran (Mindanao)-Malabang (Mindanao)	48	"
Malabang-Parang Parang	24	"
Tucuran-Zamboanga (Mindanao)	158	"
Zamboango-Jolo (Jolo)	100	"
Zamboango-Isabela (Basilan)	18	"
Jolo-Siassi (Siassi)	50	"

In all there are 41 cable stations with 1297 miles of cable connecting them.

There was plenty of theoretical knowledge as to cables and cable methods among the officers of the Signal Corps when the development of this system was inaugurated. It is needless to say to the members of this Institute that theory and practice are two different things. Thanks to the resourcefulness of the American soldiers and the American officers, supplemented by most valuable advice from the civilian cable engineers, Hamilton and Winter, the officers and men of the Signal Corps speedily developed into a most efficient cable force. Whether it was a question of laying, recovering, splicing, repairing or installing, the time soon came when work of this character was done with clockwork regularity and with the greatest economy of time and effort.

It may be of interest to state that prophesies were not lacking that American-made cable would not suit the physical conditions of the Philippine archipelago. As an answer, it may be said that of the 29 separate submarine cables installed, not one has failed through defects of manufacture or installation. The only interruptions have been due to mechanical injuries arising almost entirely from ships' anchors and similar accidents. Perhaps there may be considered one exception, where a small piece of

cable developed some weaknesses in insulation during the installation, which being removed, the cable has worked uninterruptedly for the past 18 months. It may be added that large quantities of this cable, owing to scarcity of funds, were made under Signal Corps specifications of the cheapest possible type consistent with the work expected of it, scarcely exceeding one ton per statute mile.

It is not the purpose of this paper to speculate upon the future telegraphic conditions in the Philippines, but to attempt to show under what novel and difficult conditions the pioneer work in this field has been accomplished by the Signal Corps. The use of the best or most approved telegraphic methods, common in this or other countries, has not always been considered advisable, for the men are in most cases so much needed to fill the vacancies due to breakdowns in health, on account of the trying tropical climate, that little opportunity for preliminary training has been afforded. Furthermore, the great distance from the base of supplies makes it necessary to be very conservative in adopting appliances not proved efficient by long tests under similar conditions. The value of the telegraphic and cable work of the Signal Corps has been referred to in almost every report from district, department and division commanders, so it is pleasant to feel that success has crowned the work of the corps, and a good foundation has been laid for those who come after.

This resumé of the past would not be complete without a brief allusion to the cable situation in the Orient. It is a matter of record that France, Germany, Great Britain, Holland and Russia have greatly extended their cable facilities along the Asiatic coast. All island colonies have been or are now in the process of connection by cables with the principal colonial stations of each nation of the Asiatic mainland. Alone of all countries the United States, which has constructed in an unparalleled short time a magnificent system of nearly 8,000 miles of telegraph lines and cables in the Philippine archipelago, refrains from taking steps to connect this archipelago either with Japan to the north, Australia to the south, or most important, with China to the west. It is believed that the engineering interests of the United States, which have forged to the front in Europe and Africa, will at an early date insist on additions which will foster the growth of American industry and commerce in the far East.

A paper presented at the 166th Meeting of the American Institute of Electrical Engineers, at New York, May 28, 1902.

THE REASONS FOR THE CHANGE OF THE NAVY STANDARD VOLTAGE FROM 80 TO 125.

BY LIEUT. W. V. N. POWELSON, U. S. N.

Before proceeding to a discussion of the considerations which led to the recent adoption by the Navy Department of 125 volts as the standard for all new installations on board ship, it may not be out of place to review briefly the history of the voltages used by the navy.

In the first installations, and previous to 1888, two voltages were used on board the same vessel. Generators of 110 volts were used for supplying power for the incandescent lights and generators of 50 volts were employed for the operation of the searchlights.

In May, 1888, a board was appointed to decide upon a single standard voltage at which power might be supplied to operate both the incandescent lamps and the searchlights. This board as a compromise selected a voltage of 80, the mean of the voltages already in use.

One very important consideration at that time which prevented the adoption of the commercial voltage of 110 as the standard was no doubt the apparently enormous waste of energy in the rheostat that had to be employed to cut down the voltages from 110 to about 45, the arc voltage of the searchlights at that time.

It must be remembered that the searchlights in the early installations required a very large percentage of the total electrical energy developed on board ship, and therefore their position was a most important one in any discussion affecting the

voltage of the generators. Now the position occupied by the searchlights in relation to the total power developed is minor.

Since 1888 the standard voltage of the generators on board ship has been 80, and the difference of potential between all distributing lines has been 80 volts except in the *Kearsarge*, and in the *Kentucky*, battleships of about 12,000 tons, commissioned in 1899. In these ships a new and radical departure was made in the system of distributing power. The generators were wound for 80 volts, but the wiring arrangements were such as to permit of the transmission of energy on either the two-wire 80-volt system or the three-wire system with 160 volts difference in potential between the outside wires. Although a discussion of the advantages and disadvantages of this system compared with an 80-volt two-wire system would no doubt prove of interest, it is beyond the scope of the present paper.

The attention of the Navy Department, in 1901, was strongly drawn to the necessity of changing the standard voltage 80 by the difficulty which was experienced in the purchase of electrical material owing to its special character, and one year ago a board was appointed to consider again the question of a standard voltage for the navy. Since any increase of voltage would permit of a reduction in the size of the transmission lines, it was desired to raise the voltage to that limit where the advantages to be derived from this circumstance began to be outweighed by certain disadvantages.

These disadvantages might result from the difficulty of making lamps for the particular voltage, from the fact that the voltage was not commercial or from the danger from shocks, bad arcing, grounds and electrolytic action due to moisture getting into the water-tight boxes.

The voltages from which the choice might be made were 110, 125, 220, 250, 500 and 550. In view of the recommendation of the Committee on Standards of this INSTITUTE the choice was narrowed down to 125, 250 and 550 volts. One hundred and ten volts was passed because 125 volts possessed all the advantages of a 110-volt system with certain additional advantages, and no additional disadvantages except in the matter of operation of the searchlights. At that time the plant of the *Kearsarge* had been running for some months with a difference of potential of 160 volts between wires and no bad effects had been noted from shocks, arcing, grounds or electrolytic

action, and no trouble on this score was therefore to be expected from the use of 125 volts.

Two hundred and fifty and 550 volts were discarded for the following reasons:

(*a*) The difficulty that it was expected would accompany the purchase of satisfactory incandescent lamps.

(*b*) The additional waste of power in operating searchlights.

(*c*) The probable necessity of re-designing the standard wiring appliances.

(*d*) The very large increase over any voltage formerly used on board ship.

In considering the question of a change of voltage inquiry was made to determine:

(*a*) What advantages would be secured by the adoption of a voltage from the mere fact that it was commercial, irrespective of any consideration of its absolute value.

(*b*) What effect would a change to the most suitable commercial voltage have upon the cost and weight of electrical apparatus used on board ship.

(*c*) What effect would a raise in voltage have upon the efficiency of operation of electrical apparatus on board ship.

Advantages of Using a Commercial Voltage.

An advantage which is always sure to follow the adoption of a commercial article is a large reduction in the time of delivery and in any naval organization this may become of supreme importance. It does not always follow that a reduction in price will result. This will depend upon how special the former apparatus was and in how large quantities it was purchased. Take for instance the incandescent lamps. The navy has been buying a special 16 c.p. lamp of 80 volts, 3.8 watts efficiency and equipped with a bulb of special shape. Notwithstanding the special character of this lamp the navy has not paid a higher price than a commercial lamp would cost, for two reasons:

(*a*) Because the limits of variation in volts and watts per candle at the rated candle power have been so large, viz: 78 to 82 volts and 3.6 to 4.0 watts, and

(*b*) Because lamps have been ordered in fairly large quantities.

It must be apparent that if a special voltage is used a purchaser must pay more for his lamps than the price of a commercial article, or he must allow such variations in the volts

and watts per candle as will permit a manufacturer to make up a lot of lamps practically all of which will fall between the limits allowed. If the limits are so narrow that on an average only half of the finished lamps fall between the allowed limits, the manufacturer must charge double if the voltage is so special that the other lamps cannot be sold.

If a purchaser who has been buying lamps of special voltage orders lamps, however, of any voltage between 100 and 125, he may reduce the limits of variation in volts and watts per candle without any increase in price because there is a demand for lamps of all voltages from 100 to 125, and the lamps which fall outside his limits may readily be sold to someone else and the manufacturer suffers no loss. In the purchase of lamps, therefore the advantages to be derived from the adoption of a commercial voltage are:

(*a*) quick deliveries,
(*b*) closer selection.

These advantages will, however, not be secured if any of the required features of the lamps are special. A special shape of bulb or a special wattage would at once defeat both of the advantages which might be derived.

In the matter of generators and motors the possible advantages to be derived from the adoption of a commercial voltage are:

(*a*) quick deliveries,
(*b*) decreased cost.

Whether or not these advantages will be secured, depends almost entirely upon whether the navy adopts the heating limits allowed in commercial work, *i. e.*, the limits recommended by the Committee on Standards of this INSTITUTE.

The navy's heating limits are at the present time considerably below the commercial limits and a commercial generator or motor must be re-designed in its windings and re-rated at a lower rating in order to meet the navy specifications. Unless the commercial heating limits are adopted, our generators and motors will still be special and no advantage, either in price or time of delivery, is likely to follow a change to a commercial voltage.

In the matter of insulated wire, however, a change to a commercial voltage will secure the only advantage possible—that of decreased cost—and this advantage will be fully obtained without regard to the special character of the wire used, for

the reason that any increase in voltage will permit the size of wire to be reduced and the navy standard thickness of insulation is strong enough to withstand easily any commercial low tension voltage.

In order to determine how much of a saving in cost and weight of wire and conduit would result in a battleship of the size of the *Kearsarge* if the voltage were raised from 80 to 125 when using a plain two-wire system, certain calculations were made as shown in Tables 1 to 9.

So much has been claimed for the three-wire system as installed on the *Kearsarge* in the matter of saving in cost and weight of wire that it was decided to include in the tables above mentioned the cost and weight of the wiring as actually installed so that a comparison might also be made between this system and the two-wire 125-volt system.

Before proceeding to a discussion of the tables it would be well to consider briefly the system of transmission actually installed on the *Kearsarge*. This system is shown diagrammatically in Fig. 1.

From the dynamo-room, power is transmitted to distributing boards forward and aft. The transmission is divided into two sections—one for power and one for lighting. Energy is distributed from the dynamo-room to the larger distribution boards on the three-wire system, employing five wires, the neutral being common to both power and lighting systems. From the distribution boards all the lighting is on the two-wire 80-volt system, while the power distribution is, with the exception of certain small motor circuits, all on the three-wire system. All the switchboards are, however, so arranged that the outside wires of the three-wire system may be placed in parallel, so that any part of the system may be worked with only one dynamo in operation at a pressure of 80 volts. In order that the system might be thus operated it was necessary to make the neutral wire of the power system the same size as the outside wires, for the reason that the neutral must when thus employed take the sum of the currents in the outside wires. When working under 80 volts pressure the current taken by the motors is approximately one-half the full load current, so that under these working conditions the neutral is taking a current equal to the full load current of an outside wire, when working the motors at 160 volts, and the neutral must therefore have the same section as the outside wires.

Weights.

Electric Machinery.—The weight of a dynamo or motor of a given output is practically independent of the voltage for which it is wound. The only dimensions of such machines that would vary appreciably for a given output with a moderate change of voltage would be the commutator dimensions. The surface of a commutator would vary inversely as the voltage and its weight in a somewhat smaller proportion. It is estimated that a saving of not more than 1½% in the total weight of a generating set could be effected by increasing its voltage from 80 to 125, and of not more than 2% in the weight of an enclosed motor by a similar increase in voltage. This saving would result only on the assumption that each machine was accurately designed for its rated voltage. In practice it is doubtful whether there would be any saving at all, for it is the custom to work up standard commercial forms into something that will be just under the weight limit allowed by specifications

Transmission Lines.—Except in a very few cases the size of all transmission lines on board ship is determined on the basis of a certain maximum allowable drop in voltage between the switchboard and the last lamp or motor, as the case may be. In other words, the lines are calculated for a given allowable percentage of loss of energy under full load. If, therefore, two transmitting systems of different potential are to be directly comparable, as regards the size of conductors, each must give the same efficiency of transmission. The sizes of the conductors in the two systems would vary in section inversely as the square of the voltage of the systems. In a 125-volt system, therefore, conductors could be employed having but 41% of the copper section of conductors in an 80-volt system. The total weight of the corresponding insulated wires in the two systems would not, however, have the fixed ratio of 41%, because the weight of the insulation is not a fixed percentage of the total weight of the wire for all sizes. The thickness of the navy standard insulation is practically independent of the size of wire, and hence in the smaller wires it is a larger proportion of the total weight of wire than in the larger sizes. This is shown in Table 1, column 5. There is a certain saving in weight due to an increase in voltage on all wires except No. 14 B. & S. of 4,000 cm., and the double conductor of seven strands of No. 22 B. & S. used so largely in portables. It was not con-

TABLE I.

SHOWING THE DETAILED COST AND WEIGHT OF BOTH INSULATION AND COPPER OF WIRES USED AS FEEDERS ON KENTUCKY AND KEARSARGE.

	Circular mills of copper in feeders. (1)	Total weight of wire per foot. (2)	Weight of copper per foot. (3)	Weight of insulation per foot. (4)	Percentage of total weight of wire. (5)		Total cost of insulated wire per foot. (6)	Cost of copper in wire per foot. (7)	Cost of insulation on wire per ft. (8)	Percentage of total cost of wire. (9)	
					Copper.	Insulation.				Copper.	Insulation.
1	1,321,308	4.60	4.00	.600	87.0	13.0	1.60	.80	.80	50.0	50.0
2	1,045,718	3.60	3.16	.440	87.8	12.2	1.33	.632	.698	47.5	52.5
3	829,310	2.90	2.51	.390	86.5	13.5	1.05	.502	.548	47.8	52.2
4	657,606	2.313	1.986	.327	86.0	14.0	.84	.397	.443	47.2	52.8
5	521,589	1.885	1.570	.315	83.3	16.7	.72	.314	.406	43.6	56.4
6	413,639	1.553	1.250	.303	80.5	19.5	.56	.250	.310	44.5	55.5
7	373,737	1.420	1.129	.291	79.5	20.5	.48	.226	.254	47.0	53.0
8	296,387	1.138	.895	.243	78.6	21.4	.39	.179	.211	46.0	54.0
9	250,527	.970	.756	.214	78.0	22.0	.35	.1512	.1988	43.2	56.8
10	198,677	.794	.599	.195	75.5	24.5	.30	.1198	.1802	40.0	60.0
11	157,563	.647	.475	.172	73.5	26.5	.25	.0950	.1550	38.0	62.0
12	124,928	.546	.378	.168	69.4	30.6	.22	.0756	.1444	34.4	65.6
13	99,064	.463	.299	.164	64.5	35.5	.20	.0598	.1402	29.9	70.1
14	75,776	.371	.229	.142	61.8	38.2	.15	.0458	.1042	30.5	69.5
15	60,088	.314	181	.133	57.6	42.4	.12	.0362	.0838	30.2	69.8
16	49,077	.260	.148	.112	57.2	42.8	.10	.0296	.0704	29.6	70.4
17	38,912	.218	.117	.101	53.5	46.5	.09	.0234	.0666	26.0	74.0
18	30,912	.184	.093	.091	50.5	49.5	.08	.0186	.0614	23.2	76.8
19	22,779	.165	.069	.096	42.0	58.0	.075	.0138	.0612	18.4	81.6
	Average	1.28					.47				

TABLE II.

TABLE SHOWING THE PERCENTAGE IN COST AND WEIGHT OF THE WIRES WHICH WILL GIVE THE SAME EFFICIENCY IN TRANSMISSION OF POWER UNDER A 125 VOLT SYSTEM, AS THE WIRES IN TABLE I WILL GIVE UNDER THE 80 VOLT SYSTEM.

	C.M. of copper in 125 v. cable. Comp. to wires in table 1. 41 per cent. of col. 1, table 1. (10)	Calculated wt. of cu. in. wire = 41 per cent. of col. 3, table 1. (11)	Calculated wt. of ins. on wire = 64 per cent. of col. 4, table 1. (12)	Calculated weight of ins. wire per foot. (13)	Actual wt. of ins. wire per foot from tables. (14)	Total cost of insulated wire per foot. (15)	Col. 14/col 2. Ratio of total wt. of wire in 125 v.sys. to wt. in 80 v. sys. (16)	Col. 15/col. 6 Ratio of total cost of wire in 125 v. sys. to cost in 80 v. sys. (17)
1	542,000	1.64	.384	2.024	1.95	.74	.424	.463
2	430,000	1.29	.282	1.572	1.60	.58	.445	.443
3	340,000	1.03	.250	1.280	1.30	.44	.448	.419
4	270,000	.813	.209	1.022	1.04	.37	.449	.440
5	214,000	.645	.203	.848	.85	.32	.451	.444
6	169,500	.512	.194	.706	.695	.265	.447	.473
7	153,000	.463	.186	.649	.634	.246	.456	.513
8	121,500	.366	.156	.522	.533	.217	.469	.553
9	102,500	.310	.137	.447	.473	.202	.487	.577
10	81,500	.246	.125	.371	.394	.163	.496	.544
11	64,500	.195	.110	.305	.330	.129	.510	.516
12	51,200	.155	.108	.263	.270	.102	.495	.464
13	40,500	.123	.105	.228	.225	.092	.486	.460
14	31,000	.094	.091	.185	.188	.081	.506	.540
15	24,600	.074	.085	.159	.170	.076	.542	.634
16	20,100	.061	.072	.133	.145	.070	.560	.700
17	15,950	.048	.065	.113	.128	.0636	.585	.650
18	12,620	.038	.058	.096	.114	.0590	.610	.675
19	9,350	.028	.061	.089	.1065	.0510	.645	.680
	Average. . . .				.587	.225		

TABLE III.

SHOWING SIZE AND COST OF ENAMELED CONDUIT FOR FEEDERS OF VARIOUS SIZES USED ON THE KENTUCKY AND KEARSARGE.

	Size of feeders in 80-volt system from column 1. (18)	Overall diameter of wire. (19)	Standard size of conduit (20) Wires per tube.	Bore.	I. P. S	Clearance. (21)	Weight of conduit per foot of conductor (22)	Cost of conduit per foot of conductor. (23)
1	1,321,308	1.688	1	2.06	2″	.313	Lbs.3.61	$.23
2	1,045,718	1.520	1	2.06	2″	.540	3.61	.23
3	829,310	1.375	1	1.58	1½″	.205	2.68	.17
4	657,606	1.250	1	1.58	1½″	.330	2.68	.17
5	521,589	1.156	1	1.58	1½″	.424	2.68	.17
6	413,639	1.062	1	1.35	1½″	.290	2.24	.13
7	373,737	1.031	1	1.35	1½″	.320	2.24	.13
8	296,387	.937	1	1.35	1½″	.413	2.24	.13
9	250,527	.875	1	1.35	1½″	.475	2.24	.13
10	198,677	.813	1	1.02	1″	.208	1.67	.11
11	157,563	.750	1	1.02	1″	.270	1.67	.11
12	124,928	.718	1	1.02	1″	.302	1.67	.11
13	99,064	.687	2	1.58	1½″	.206	1.34	.085
14	75,776	.625	2	1.35	1½″	.100	1.12	.07
15	60,088	.593	2	1.35	1½″	.164	1.12	.07
16	49,077	.563	2	1.35	1½″	.225	1.12	.07
17	38,912	.531	2	1.35	1½″	.288	1.12	.07
18	30,912	.500	2	1.35	1½″	.350	1.12	.07
19	22,779	.500	2	1.35	1½″	.350	1.12	.07
	Average. . .						Lbs. 1.96	.122

TABLE IV.

SHOWING THE PERCENTAGE IN COST AND WEIGHT OF THE ENAMELED CONDUIT FOR WIRES WHICH WILL GIVE THE SAME EFFICIENCY IN TRANSMISSION OF POWER UNDER A 125 VOLT SYSTEM, AS THE WIRES IN TABLE 3 WILL GIVE UNDER AN 80 VOLT SYSTEM.

Size of feeders in 125-volt system from column 10.	Overall diameter of wire.	Standard size of conduit. (26)			Clearance.	Weight of conduit per foot of conductor.	Cost of conduit per foot of conductor.	Ratio of cost of conduit for 125-v. system to cost of cond. for 80 v. sys. Col. 29/col. 23.	Ratio of wt. of conduit for 125 v. system to wt. of cond. for 80 v. sys. Col. 28/col. 22
(24)	(25)	Wires per tube.	Bore.	I. P. S.	(27)	(28)	(29)	(30)	(31)
1	542,000	1.170	1	1.38	1¼″	.410	Lbs. 2.68	$ .170	.740	.742
2	430,000	1.075	1	1.35	1¼″	.275	2.24	.130	.565	.620
3	340,000	.980	1	1.35	1¼″	.370	2.24	.130	.765	.835
4	270,000	.902	1	1.35	1¼″	.448	2.24	.130	.765	.835
5	214,000	.830	1	1.02	1″	.190	1.67	.110	.648	.623
6	169,500	.770	1	1.02	1″	.250	1.67	.110	.847	.745
7	153,000	.750	1	1.02	1″	.270	1.67	.110	.847	.745
8	121,500	.712	2	1.58	1¼″	.156	1.34	.085	.655	.598
9	102,500	.690	2	1.58	1¼″	.200	1.34	.085	.655	.598
10	81,500	.638	2	1.58	1¼″	.304	1.34	.085	.773	.803
11	64,500	.600	2	1.35	1¼″	.150	1.12	.070	.637	.680
12	51,200	.570	2	1.35	1¼″	.210	1.12	.070	.637	.680
13	40,500	.540	2	1.35	1¼″	.270	1.12	.070	.825	.835
14	31,000	.500	2	1.35	1¼″	.350	1.12	.070	1.000	1.000
15	24,600	.500	2	1.35	1¼″	.350	1.12	.070	1.000	1.000
16	20,100	.500	2	1.35	1¼″	.350	1.12	.070	1.000	1.000
17	15,950	.450	2	1.02	1″	.120	.83	.055	.786	.74(
18	12,620	.438	2	1.02	1″	.145	.83	.055	.786	.740
19	9,350	.438	2	1.02	1″	.145	.83	.055	.786	.740
	Average						Lbs. 1 46	.091		

TABLE V.

SHOWING DETAILED COST AND WEIGHT OF THE WIRE IN LIGHTING CIRCUITS ON KENTUCKY AND KEARSARGE, UNDER A TWO WIRE 80 VOLT, AND A TWO WIRE 125 VOLT SYSTEM. THE SIZES IN COLUMN 1 ARE THOSE ACTUALLY INSTALLED ON THE SHIP, EXCEPT CABLES 12 AND 13. THESE CABLES ARE FOUR TIMES THE SIZE OF THOSE INSTALLED. THESE WIRES FORM, IN THE ACTUAL INSTALLATION, PART OF A THREE WIRE SYSTEM, AND THE ONLY PART OF SUCH SYSTEM CONNECTED WITH THE LIGHTING SYSTEM. TO REDUCE THE SYSTEM TO A PURELY TWO WIRE SYSTEM, THE NEUTRAL WIRE WAS DISREGARDED, AND THE OUTSIDE WIRES INCREASED TO FOUR TIMES THE SIZE INSTALLED. THE COSTS AND WEIGHTS WERE OBTAINED FOR THE 125 VOLT SYSTEM, BY MULTIPLYING THE COSTS AND WEIGHTS FOR THE 80 VOLT SYSTEM BY THE MULTIPLIERS FROM COLUMN 16 AND COLUMN 17, TABLE 2.

	(1) Size in cm. in 80 volt 2 wire system.	(2) Length of wire in feet.	(3) Cost in 80 volt 2-wire system.	(4) Weight in 80 volt 2-wire system. in lbs.	(5) Cost in 125 volt 2-wire system.	(6) Weight in 125 v. 2-wire system in lbs.	(7) Saving in cost. Col. 3 minus col. 5.	(8) Saving in wt. Col. 4 minus col. 6. Lbs.
1	Double Cond..	9,495	$1,045.00	1,723.34	$1,045.00	1,723.34	$00.00	00.00
1	7-No.22 B & S							
2	4,107	19,314	580.00	1,098.97	580.00	1,098.97	00.00	00.00
3	9,016	1,587	79.20	163.46	47.50	90.25	31.70	73.21
4	11,368	203	10.15	21.93	6.20	13.20	3.95	8.73
5	18,081	1,833	128.20	256.62	91.50	187.60	36.70	69.02
6	22,799	1,838	137.20	303.27	93.50	195.00	43.70	108.27
7	30,856	1,785	142.70	328.07	110.40	200.00	32.30	128.07
8	38,912	1,402	126.20	305.64	89.20	178.50	37.00	127.14
9	49,077	1,030	103.00	267.80	72.10	149.60	30.90	118.20
10	60,088	1,585	190.00	497.69	126.70	286.00	63.30	211.69
11	75,776	942	142.20	349.48	81.00	176.00	61.20	173.48
12	1,654,556	486	974.00	2,800.00	457.50	1,154.00	516.50	1,646.00
13	2,630,424	84	268.00	774.00	126.00	326.00	142.00	448.00
	Two cables in parallel, each 1,315,212 c.m.							
	Total.....		$3,925.85	8,890.27	$2,926.60	5,778.46	999.25	3,111 81

TABLE VI.

SHOWING RELATIVE COSTS OF POWER WIRING ON KENTUCKY AND KEARSARGE UNDER THE 160 VOLT SYSTEM (3 WIRE) AS INSTALLED, UNDER AN 80 VOLT (2 WIRE), AND A 125 VOLT SYSTEM (2 WIRE). IN THE THREE WIRE 160 VOLT SYSTEM ACTUALLY INSTALLED, THE NEUTRAL IS OF THE SAME SIZE AS THE OUTSIDE WIRES.

A.

	(1) Size of power wires installed in 160 volt system (3 wire.) C. M.	(2) Total length of wire installed in the 3-wire system in feet.	(3) Total length of wire in any 2-wire system in feet. ¼ of col. 2.	(4) Size in c.m. in 80 volt 2-wire system. 4 × col. 1.	(5) Size in c.m. in 125 volt 2-wire system. 41 per cent. col. 4.	(6) Cost in 160 volt system (3-wire) as installed.	(7) Cost for 80 volt 2-wire system.	(8) Cost for 125 volt 2-wire system.	(9) Weight for 160 volt system (3-wire) as installed. Pounds.	(10) Weight for 80 volt 2-wire system. Pounds.	(11) Weight for 125 volt 2-wire system. Pounds.
1	22,799	2,180	1,452	89,196	36,600	$163.50	$256.10	$129.25	360.20	667.50	328.00
2	30,856	898	600	123,424	50,600	71.80	130.30	65.30	165.23	330.00	155.00
3	38,912	683	455	155,648	63,800	61.50	112.25	56.30	148.89	296.00	135.50
4	49,077	2,270	1,513	196,308	80,100	227.00	447.50	220.00	590.20	1,191.50	543.00
5	60,088	1,660	1,170	240,352	98,500	199.50	392.60	193.50	521.87	1,089.00	496.00
6	75,776	1,524	1,016	303,104	124,200	228.10	405.00	192.20	566.40	1,185.00	540.00
7	99,064	696	462	396,256	162,300	139.20	257.00	119.50	322.25	489.00	221.10
8	124,928	424	283	499,712	223,000	93.30	195.30	88.00	236.17	505.00	226.50
9	157,568	902	602	630,252	258,100	225.50	485.00	228.00	583.59	1,340.00	610.00
10	198,677	507	338	794,708	325,800	152.10	340.00	154.50	402.56	940.00	427.50
11	250,527	1,056	704	1,002,108	411,000	369.00	895.00	405.00	1,024.32	2,440.00	1,085.00
12	296,387	296	197	1,185,548	486,500	115.00	283.00	122.50	336.85	805.00	336.00
13	413,639	181	121	1,654,556	678,500	101.30	242.00	105.00	281.09	698.00	290.00
14	657,606	1,363	883	2,630,424	1,078,000	1,190.00	2,817.00	1,163.00	3,271.20	8,000.00	3,296.00
15	829,310	456	304	3,316,930	1,365,000	478.00	1,280.00	504.00	1,321.00	3,465.00	1,440.00
	Total					3,814.80	8,518.05	3,746.05	10,131.82	23,431.00	10,129.60

B.

In Column I. the Actual Sizes of the Wires Installed are given. These Wires are run on an 80 volt Two Wire System. to certain of the Smaller Motors, etc.

(1) Sizes actually installed on an 80 volt two-wire system.	(2) Actual length installed. Feet.	(3) Total length of wire in any 2-wire system Feet.	(4) Size in cm. in 80 volt 2-wire system.	(5) Size in cm. in 125 volt 2-wire system. 41 per cent. col. 4.	(6) Cost as installed.	(7) Cost for 80 volt two-wire system.	(8) Cost for 125 volt two-wire system.	(9) Weight as installed. Pounds.	(10) Weight for 80 volt 2-wire system. Pounds.	(11) Weight for 125 volt 2-wire system. Pounds.
1 4,107	285	285	4,107	4,107	$8.55	$8.55	$8.55	16.22	16.22	16.22
2 9,016	922	922	9,016	4,107	45.08	45.08	27.66	92.27	92.27	52.50
3 11,368	432	432	11,368	4,660	25.92	25.92	21.50	46.87	46.87	33.26
4 18,081	160	160	18,081	7,400	11.20	11.20	8.00	22.40	22.40	16.00
5 22,799	110	110	22,799	9,310	8.25	8.25	5.61	18.15	18.15	11.60
6 49,077	200	200	49,077	20,100	20.00	20.00	14.00	52.00	52.00	29.00
7 99,064	320	320	99,064	40,500	64.00	64.00	29.12	148.16	148.16	74.22
Total ...					183.00	183.00	114.44	396.07	396.07	232.80
Total from " A " ...					3,814.80	8,518.05	3,746.05	10,131.82	23,431.00	10,129.60
Grand Total ...					3,997.80	8,701.05	3,860.49	10,527.89	23,827.07	10,362.40

Saving in cost of wire alone in the 160v. (3 wire) system, as installed, over the 80v. (2 wire) system	$5,618.33
" " " " " " " 125v. (2 wire) " over the 80v. (2 wire) system	6,087.65
" " " " " " " " " " " " 160v. (3 wire) system as installed	469.32

Saving in weight of wire alone in the 160v. (3 wire) system, as installed, over the 80v. (2 wire) system	Lbs. 15,916.82
" " " " " " " 125v. (2 wire) " over the 80v. (2 wire) system	" 17,283.33
" " " " " " " " " " " " 160v. (3 wire) system as installed	" 1,366.51

	Insulated Wire. Cost.	Weight.
Ratio of 160 v. (3 wire) sys. as installed to 80 v. (2 wire) system	.588	.553
" " 125v. (2 wire) sys. to 80v. (2 wire) sys	.554	.515
" " " " " 60v. (3 wire) sys. as installed	.938	.930

Table Showing Detailed Costs and Weights of the Wiring on U. S. S. Kearsarge and Kentucky Under the Three-Wire 160 Volt System as Installed. A 2 wire 80 volt System, and a 2 wire 125 volt System.

TABLE VII.

DYNAMO AND EQUALIZER LEADS.

THESE WOULD BE THE SAME FOR A THREE WIRE AS FOR A TWO WIRE SYSTEM, IF THE GENERATORS WERE WOUND FOR THE SAME VOLTAGE IN EACH, BUT IN CHANGING DYNAMO E.M.F. FROM 80 TO 125 VOLTS, AND KEEPING CURRENT DENSITY IN LEADS THE SAME, A REDUCTION CAN BE MADE IN THE SIZE OF THE LEADS, IN THE PROPORTION OF 80 TO 125. THE EQUALIZER LEADS WERE KEPT AT THE ORIGINAL SIZE AS INSTALLED.

Size in C.M. 80 volts.	Size in C.M. 125 volts.	Length in ft.	Wt. in lbs. at 80 volts.	Wt. in lbs. at 125 volts	Cost at 80 volts.	Cost at 125 volts.
4,106	4,106	455	25.89	25.89	$13.65	$13.65
30,856	19,750	306	56.30	44.17	24.48	21.10
38,912	25,400	112	24.42	14.05	10.08	8.96
829,310	530,000	181	570.15	344.00	190.00	133.00
1,045,718	672,000	399	1,455.20	997.00	530.00	343.66
Equal'r lead						
1,045,718	1,045,718	199	727.50	727.50	265.00	265.00
Total.....			2,859.46	2,152.61	1,033.21	785.37

TOTAL COSTS AND WEIGHTS.	As installed. A combination of an 80 volt 2-wire, and a 160 volt 3-wire system	80 volt 2-wire system.	125 volt 2-wire system.	Ratio of 125 volt 2-wire system, to 80 volt 2-wire system.
TOTAL COSTS.				
Insulated Wire for Power.....	3,997.80	$8,701.05	$3,860.49	.444
" " " Light	3,010.77	3,925.85	2,926.60	.745
" " " Dynamo and Equalizer Leads.....	1,033.21	1,033.21	785.37	.760
	$8,041.78	$13,660.11	$7,572.46	.551
TOTAL WEIGHTS.				
Insulated Wire for Power.....	10,527.89	27,827.07	10,362.40	.435
" " " Light	6,272.63	8,890.27	5,778.46	.650
" " " Dynamo and Equalizer Leads	2,859.46	2,859.46	2,152.61	.753
	$19,659.98	$35,576.80	$18,293.47	.515

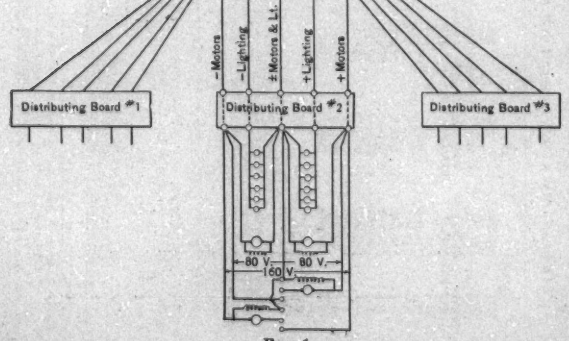


FIG. 1.

TABLE VIII.

TABLE SHOWING THE SAVING IN COST AND WEIGHT OF ENAMELED CONDUIT IN THE LIGHTING SYSTEM OF THE KEARSARGE THAT WOULD RESULT IF WIRED FOR A 125 VOLT TWO WIRE SYSTEM, INSTEAD OF AN 80 VOLT TWO WIRE SYSTEM; ASSUMING ALL WIRE TO BE IN CONDUIT.

THE 80 VOLT SYSTEM.

	(1) Size of wire in c.m.	(2) Feet of wire used.	(3) Diam. over insulation.	(4) Size of conduit. I. P. S.	(5) Bore.	(6) Wires per tube.	(7) Weight of conduit per foot of wire.	(8) Clearance.	(9) Cost of conduit per foot of wire.	(10) Total cost.	(11) Total weight of conduit.
1	4,107	19,314	.3438	¾″	.82	2	Lbs. .56	.133	$0.040	$772.00	Lbs. 10,820
2	9,016	1,587	.4375	1″	1.02	2	.83	.145	.055	87.30	1,320
3	11,368	203	.4375	1″	1.02	2	.83	.145	.055	11.15	168
4	16,081	1,833	.4688	1¼″	1.35	2	1.12	.413	.070	128.20	2,050
5	22,799	1,838	.5000	1¼″	1.35	2	1.12	.350	.070	128.50	2,060
6	30,856	1,785	.5000	1¼″	1.35	2	1.12	.350	.070	125.00	2,000
7	38,912	1,404	.5312	1¼	1.35	2	1.12	.290	.070	98.30	1,574
8	49,077	1,030	.5625	1¼″	1.35	2	1.12	.225	.070	72.00	1,170
9	60,088	1,585	.5938	1¼″	1.35	2	1.12	.165	.070	111.00	1,774
10	75,776	942	.6250	1¼″	1.35	2	1.12	.100	.070	66.00	1,055
11	1,654,776	486	*1.3750	1¼″	1.58	½	5.36	.205	.340	165.00	2,600
12	2,630,424	84	*1.6875	2″	2.06	½	7.72	.313	.480	40.30	650
	Total									$1,804.75	27,241

THE 125 VOLT SYSTEM.

	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
1	4,107	19,314	.3438	¾″	.82	2	Lbs. .56	.133	$.040	$772.00	Lbs. 10,820.0
2	4,107	1,587	.3438	¾″	.82	2	.56	.133	.040	63.48	889.0
3	4,660	203	.3500	¾″	.82	2	.56	.120	.040	8.12	117.0
4	7,400	1,833	.4000	1″	1.02	2	.83	.220	.055	101.00	1,520.0
5	9,350	1,838	.4375	1″	1.02	2	.83	.145	.055	101.15	526.0
6	12,620	1,785	.4400	1″	1.02	2	.83	.140	.055	98.00	1,480.0
7	15,950	1,404	.4480	1¼″	1.35	2	1.12	.454	.070	98.30	1,574.0
8	20,100	1,030	.4800	1¼″	1.35	2	1.12	.390	.070	72.00	1,170.0
9	24,600	1,585	.5000	1¼″	1.35	2	1.12	.350	.070	111.00	1,774.0
10	31,000	942	.5050	1¼″	1.35	2	1.12	.340	.070	66.00	1,055.0
11	678,000	486	1.3000	1¼″	1.58	1	2.68	.280	.170	82.50	1,300.0
12	1,078,000	84	1.5400	2″	2.06	1	3.61	.520	.240	20.15	325.0
	Total									$1,593.70	23,550.0

*Two Cables in Multiple each of the Diameter Specified.

TABLE IX.

TAPLE SHOWING THE SAVING IN COST AND WEIGHT OF ENAMELED CONDUIT IN THE POWER SYSTEM OF THE KEARSARGE THAT WOULD RESULT IF WIRED FOR A 125 VOLT TWO WIRE SYSTEM, INSTEAD OF AN 80 VOLT TWO WIRE SYSTEM; ASSUMING ALL WIRE TO BE IN CONDUIT.

	(1) Size of wire in the 80 volt system in cm.	(2) Feet of wire used.	(3) Diam. over insulation.	(4) Size of conduit. I. P. S.	(5) Size of conduit. Bore.	(6) Wires per tube.	(7) Weight of conduit per foot of wire.	(8) Clearance.	(9) Cost of conduit per foot of wire.	(10) Total cost.	(11) Total weight of conduit in the 80 volt system.
1	4,107	285	.3438	½″	.82	2	Lbs. .56	.133	$.040	$11.40	Lbs. 159.5
2	9,016	922	.4375	1″	1.02	2	.83	.145	.055	50.70	765.0
3	11,368	432	.4375	1″	1.02	2	.83	.145	.070	23.80	358.0
4	18,081	160	.4688	1¼″	1.35	2	1.12	.413	.070	11.20	179.0
5	22,799	110	.5000	1¼″	1.35	2	1.12	.350	.070	7.70	123.0
6	49,077	200	.5625	1¼″	1.35	2	1.12	.225	.070	14.00	224.0
7	99,064	320	.6875	1½″	1.58	2	1.34	.205	.085	27.20	428.0
8	89,196	1,452	.6562	1½″	1.58	2	1.34	.267	.085	123.30	1,945.0
9	123,424	600	.7187	1½″	1.58	2	1.34	.140	.085	51.00	804.0
10	155,648	455	.7500	1″	1.02	1	1.67	.270	.110	50.05	760.0
11	196,308	1,513	.8125	1″	1.02	1	1.67	.208	.110	166.43	2,520.0
12	240,352	1,170	.8500	1¼″	1.35	1	2.24	.500	.130	152.00	2,620.0
13	303,104	1,016	.9375	1¼″	1.35	1	2.24	.413	.130	131.30	2,270.0
14	396,256	462	.9667	1¼″	1.35	1	2.24	.383	.130	60.00	1,070.0
15	499,712	283	1.1250	1½″	1.58	1	2.68	.455	.170	48.10	760.0
16	630,252	602	1.2500	1½″	1.58	1	2.68	.330	.170	102.30	1,620.0
17	794,708	338	1.3400	1½″	1.58	1	2.68	.240	.170	57.50	905.0
18	1,002,108	704	1.5200	2″	1.58	1	3.61	.560	.230	162.00	2,540.0
19	1,182,548	197	1.5750	2″	2.06	1	3.61	.485	.230	45.30	710.0
20	1,254,556	121	1.6500	2″	2.06	1	3.61	.410	.230	27.83	437.0
21	2,630,424	883	*1.6875	2″	2.06	½	7.22	.373	.460	406.00	6,375.0
22	3,316,930	304	†1.5600	2″	2.06	⅓	10.83	.500	.690	210.00	3,294.0
	Total									1,939.11	30,866.5

*Two Cables in Multiple each of the Diameter Specified.
†Three Cables in Multiple each of the Diameter Specified.

TABLE IX.—*Continued.*

	(12) Size of wire in the 125 volt system in cm.	(13) Feet of wire needed.	(14) Diameter of wire over insulation.	(15) Size of conduit. I. P. S.	(16) Size of conduit. Bore.	(17) Wires per tube.	(18) Weighf of conduit per foot of wire.	(19) Clearance.	(20) Cost of conduit per foot of wire.	(21) Total cost.	(22) Total weight of conduit in the 125 volt system.
1	4,107	285	.3438	½″	.82	2	Lbs. .56	.133	$0.040	$11.40	Lbs. 159.5
2	4,107	922	.3438	½″	.82	2	.56	.133	.040	36.88	516.5
3	4,660	432	.3550	½″	.82	2	.56	.110	.040	17.28	242.0
4	7,400	160	.3900	1″	1.02	2	.83	.240	.055	8.80	133.0
5	9,350	110	.4375	1″	1.02	2	.83	.145	.055	6.05	91.3
6	20,100	200	.5000	1¼″	1.35	2	1.12	.350	.070	14.00	224.0
7	40,500	320	.5312	1¼″	1.35	2	1.12	.288	.070	22.40	358.0
8	36,600	1,452	.5160	1¼″	1.35	2	1.12	.318	.070	101.64	1,625.0
9	50,600	600	.5625	1¼″	1.35	2	1.12	.225	.070	42.00	672.0
10	63,800	455	.6000	1¼″	1.35	2	1.12	.150	.070	31.85	510.0
11	80,100	1,513	.6300	1½″	1.58	2	1.34	.320	.085	128.60	2,025.0
12	98,500	1,170	.6875	1½″	1.58	2	1.34	.205	.085	99.40	1,565.0
13	124,200	1,016	.7187	1½″	1.58	2	1.34	.143	.085	86.50	1,360.0
14	162,300	462	.7812	2″	2.06	1	1.67	.238	.110	50.82	770.0
15	205,000	283	.8197	1″	1.02	1	1.67	.200	.110	31.13	472.0
16	258,100	602	.9000	1¼″	1.35	1	2.24	.450	.130	78.10	1,348.0
17	325,800	338	.9400	1¼″	1.35	1	2.24	.410	.130	44.00	757.0
18	411,000	704	1.0700	1¼″	1.35	1	2.24	.280	.130	91.40	1,575.0
19	486,500	197	1.1000	1¼″	1.35	1	2.24	.250	.130	25.60	441.5
20	514,500	121	1.1800	1¼″	1.58	1	2.68	.400	.170	20.27	324.0
21	1,078,000	883	1.5100	2	2.06	1	3.61	.550	.230	201.50	3,185.0
22	1,365,000	304	1.6900	2	2.06	1	3.61	.370	.230	70.00	1,098.0
	Total									1,219.62	19,451.8

RESUME OF CONDUIT SAVINGS ON SHIPS OF THE KEARSARGE CLASS ON THE ASSUMPTION THAT ALL WIRE IS IN CONDUIT. AS ACTUALLY INSTALLED, MANY OF THE LARGER FEEDERS ARE RUN OPEN ON PORCELAIN CLEATS.

Ratio of Cost in 125 volt two wire system to 80 volt two wire system	POWER	.629
" " " " " " " " " " " " " " " "	LIGHTING	.884
" " " " " " " " " " " " " " " "	TOTAL	.752

Ratio of Weight in 125 volt two wire system to 80 volt two wire system	POWER	.630
" " " " " " " " " " " " " " " "	LIGHTING	.865
" " " " " " " " " " " " " " " "	TOTAL	.740

sidered desirable to reduce the section of these wires, for the reason that a certain amount of mechanical strength is necessary in a wire to prevent its breaking. No fixed figure can therefore be named which will correctly represent the ratio between the aggregate weights of all the transmission lines under two different voltages. The ratio will depend very largely on the sizes of wire used. The proportional saving will be larger, the heavier the wires. In a small ship having only a lighting plant in which the No. 14 wire is used in a large proportion, the proportional saving would be smaller. The percentage of saving would therefore be different for every type of ship, and in general terms would be larger, the larger the ship. In order to determine what this saving would be, it is necessary to take each size of transmission line and calculate the particular reduction in each case due to the increase of voltage. Tables 5, 6 and 7 show a detailed calculation for the *Kearsarge* and *Kentucky* class. From this it will be seen that in these ships the ratio of the total weight of transmission lines under a 125-volt to those under an 80-volt system (two-wire in each case) is 51½%.

Table 2, column 16, gives the individual ratios of weights under the 80 and 125-volt systems for several sizes of wire used as feeders in the *Kearsarge* and *Kentucky*. This shows that the ratio varies from 42.4% to 64.5% for wires of sizes between 1,300,000 and 23,000 cm. These wires are, however, only the feeder sizes and do not include the smaller wires used as sub-mains or as branches to single outlets. An inspection of the first two lines of Table 5 will show that the double conductor and the 4,107 cm. wire form a large proportion in both cost and weight of the entire lighting system of the *Kearsarge* and *Kentucky* and on neither of these wires is there any saving due to increased voltage. The proportional saving in weight in lighting systems will therefore, on account of this small wire, always be less than in power systems. This is shown in the summary of "cost and weights," from Tables 5, 6 and 7. This summary shows the ratio of weights under a 125-volt two-wire system and an 80-volt two-wire system to be .435 in the power system, and .65 in the lighting, with the ratio .515 for the combined systems including all dynamo leads.

Conduit.—In Table 4, column 31, are shown the individual ratios of the weights of enameled conduit under the 80 and 125-

volt systems for wire sizes from 1,300,000 cm. to 23,000 cm. This shows the ratios to vary from 60% to 100%.

Tables 8 and 9 give a detailed calculation of the weight of enameled conduit for the *Kearsarge* and *Kentucky* under an 80-volt two-wire system both for the lighting system and for the power system. The results show that an increase from 80 to 125 volts results in a reduction of 13.5% in the weight of the conduit for the lighting system, and 37% in the power system. The total reduction in weight of conduit for both systems combined is 26%. As remarked under the heading of "Transmission Lines," the large amount of 4000 cm. wire common to the lighting system under each voltage materially reduces the saving in the lighting compared with that effected in the power system.

Tables 8 and 9 were calculated on the assumption that all of the wire in the ship was run in conduit. As a matter of fact, a considerable proportion of the large wire on the *Kearsarge* and *Kentucky* is run open on porcelain insulators. This practice may or may not be adhered to in the future, and it may be either expanded or contracted, so that in order to get a comparison for a fixed condition the tables were calculated upon the assumption that all wire was in conduit.

Wiring Appliances.—The weight and size of these appliances would not be affected by an increase of voltage from 80 to 125.

Switchboards.—The copper section of all bus-bars and switches in a 125-volt system could be reduced to at least 64% of the section in the 80-volt system. If reduced to 64% of the section used in the 80-volt system, the current density would remain the same in the switches and bus-bars under each system. The heating, however, would be less in the 125 than in the 80-volt system, because the radiating surface per watt lost in heat would be greater in the 125-volt system.

Costs.

Electric Machinery.—The only saving in cost in electric machinery due to an increase of voltage, would be that due to the decreased size of the commutator in the higher voltage system. Such saving in cost due to an increase from 80 to 125 volts would probably not exceed 3% in case of a generating set, and 5% in the case of an enclosed motor. Such saving would result only on the assumption that the generators and motors were accurately designed for each system of voltage. In

actual practice there would be little saving in the cost of these machines, owing to the fact that it is a common practice to work up commercial standards into such shape as will come within the weight and heating limits prescribed by the specifications.

Transmission Lines.—The cost of these would vary in the same general proportion as the weight under different voltage systems, although not exactly in the same proportion. Table 2, column 17 illustrates this point.

As pointed out under the subject of "weights," the saving due to an increased voltage will be less in the lighting than in the power systems. The ratios of costs are given in the summaries from Tables 5, 6 and 7. These show the saving in cost to be about 25½% in the lighting system, and 55.6% in the power system, giving a total saving in cost of insulated wire of 44.6% including dynamo leads.

Conduit.—In Table 4, column 30, Appendix V., are shown the individual ratios of costs of enameled conduit under the 80 and 125-volt systems for wire sizes from 1,300,000 to 23,000, cm. This shows that the ratios vary from 56.5% to 100%.

Tables 8 and 9 give a detailed calculation of the cost of enameled conduit for the *Kearsarge* and *Kentucky* under an 80-volt two-wire system and under a 125-volt two-wire system. The figures show that an increase from 80 to 125 volts results in a reduction of 11.6% in the cost of the conduit for the lighting system, and 37.1% in the power system. The total reduction in cost of the conduit for both systems combined is 24.8%.

Wiring Appliances.—The cost of these appliances would not be affected by any change in voltage from 80 to 125.

Switchboards.—As pointed out under the subject of "weights," the saving in copper will amount to about 36%. The saving in the total cost of the board cannot be calculated with accuracy for all conditions but is estimated at from 15 to 20%.

Incandescent Lamps.

As mentioned above, a change from 80 to 125 volts will not affect the price of incandescent lamps, but will admit of reducing the limits of variation allowed in voltage and watts per candle.

Efficiency of Operation.—No change in efficiency of operation of generators or motors is to be expected from a change from 80 to 125 volts. The efficiency of incandescent lamps is a matter of specification, as lamps for any reasonable effi-

ciency can be easily manufactured. It was not proposed to effect any increase in the efficiency of the transmission lines by the increase from 80 to 125 volts. For lines of equal section, the efficiency of transmission would be greater under the 125-volt system, but it was deemed best to sacrifice this advantage in favor of the reduced first cost which would be effected by so apportioning the sizes of the transmission lines that they would give equal efficiency of transmission under each system. In circuits, however, which use 4000 cm. wire under the 80-volt system, as pointed out above, there will be no saving in first cost due to the adoption of the 125-volt system, but there will be a saving in the efficiency of transmission. The losses in these circuits under the 125-volt system will be to the losses under the 80-volt system as 41 is to 100.

The searchlight is the only piece of apparatus on board ship whose efficiency of operation is seriously affected by an increase of voltage. A searchlight is merely an automatic self-regulating arc lamp mounted in front of a projector. The function of the self-regulating mechanism is to keep the voltage across the arc constant. The arc voltage therefore becomes one of the most essential features of a searchlight lamp. This arc voltage is not an inflexible quantity inherent in the character of an electric arc, but it will permit of a comparatively wide variation under certain conditions. The condition having the greatest effect on the upper limit of this permissible arc voltage is the voltage of the lines supplying power to the lamp.

It might appear on first thought that the arc voltage could be raised to approximately the line voltage. In practice, however, this is not permissible. It is absolutely essential to good regulation of the lamp that the arc voltage should be considerably below the line voltage. The amount that the arc voltage is required to be below the line voltage is dependent somewhat upon the character of the self-regulating mechanism of the arc lamp.

At the present time the searchlights of the navy are adjusted for about 50 volts at the arc. The selection of this arc voltage was dependent largely upon the line voltage of 80. The arc voltage is reduced from 80 to 50 by means of a rheostat in series with the arc, so that it is apparent that a considerable portion of the energy taken from the line is used up in the rheostat.

When the proposition to increase the navy standard voltage

was brought up, the question was presented as to whether a separate generator of low voltage should be provided for the operation of the searchlights, or whether the searchlights should be operated from 125-volt lines, using a rheostat in series with the lamp. Since the proposition to use a low voltage generator had only in view the saving of the energy dissipated in the rheostat, this proposition was decided against for the reason that the necessities of the service required that a searchlight should, at night, always be ready for instant service, and should always be under the immediate control of the officer of the deck.

In order that this condition might obtain when using special generators of low voltage, it would be necessary to keep these generators running on no load at all times during the night ready for service. The steam consumed by the engines of these generators when running on no load would very largely exceed the steam required to furnish the energy dissipated in the rheostat when using lines of higher potential.

Notwithstanding these considerations, investigations were undertaken to see to what limits it would be practicable to reduce the voltage of a generator and at the same time obtain an efficient operation of the searchlights. Extended experiments were made to determine the relation existing between line voltage, arc voltage, watts consumed at the arc, and total quantity of light. A description of these experiments, together with the results, is beyond the scope of this paper. It is sufficient to say that the experiments demonstrated that the line voltage could not be appreciably reduced below 80 volts without a bad effect upon the self-regulating properties of the searchlight, and a diminution of its intensity. It was demonstrated that with lines having a potential higher than 80, the arc voltage could be raised considerably above 50, and that the current could then be reduced somewhat without apparently changing the quantity of light.

It was found, however, that with equal illumination, the total energy taken from the line B was greater when the light was operated on lines of 110 and 125 volts than when operated on lines of 80 volts pressure. The increase, however, in the total energy taken from the line was proportionately less than the increase in the line voltage itself.

Operating Voltage on Board Ship—For the reasons and considerations substantially as given above, it was decided to adopt for the navy a voltage of about 125. It was recommended,

however, that the generators on board ship be run normally at 123 volts. Such a reduction from 125 volts to 123 volts would have no appreciable effect upon the efficiency of operation of any motor or generator designed for 125 volts, and the recommendation was made to run the generators at this voltage on account of the incandescent lamp question. To one not well acquainted with the conditions under which the navy purchases its material this question may seem of minor importance. In the actual working of the system of supplying the service with incandescent lamps the question is, however, of considerable importance, as the navy has had great difficulty in obtaining satisfactory incandescent lamps. While lamps are commercially made at all voltages from 100 to 125, there are certain voltages between these limits at which the demand for lamps largely exceeds the supply, on account of the large number of lighting plants throughout the country which are run at these voltages. There are certain voltages, however, between these points of concentrated demand where the supply considerably exceeds the demand. In selecting a voltage for the navy, therefore, it was desired to take a voltage very near the commercial standard for generators and motors, but far enough removed from the favorite lamp voltages of large lighting plants to ensure obtaining from stock on short notice such incandescent lamps as might be required At the present time the demand for 120 and 125-volt lamps exceeds the supply, and this condition will in the future no doubt grow more pronounced From every lot of lamps made for 120 volts or for 125 volts there are always found lamps of about 123 volts. These lamps are of equally as good quality as the lamps which on calibration give the rated candle power at 125 volts and 120 volts. The voltage 123 is not, and probably in the future will not be very largely used as the lamp voltage of lighting plants, and the navy will be able to obtain such lamps quickly from stock.

Practical Working of the System.—It was only last week that an opportunity was offered to test the wisdom of the adoption of the general voltage of 125 and the specific voltage of 123 for incandescent lamp purposes A collier, the U. S. S. *Ajax*, came to the Brooklyn Navy Yard, a few days ago with her generating set worn out, broken down and of no service. The ship was due to sail in seventeen days. An 8 k.w. commercial, direct connected generating set of 125 volts rating

was purchased in the open market and delivered on board ship in ten days, and the necessary number of incandescent lamps of 123 volts rating with limits of voltage from 122 to 124 were obtained in the open market and delivered within three days after the order was placed. Under the old 80-volt system, if no lamps or generating set had been in store, it would have required a considerable time to obtain them, and the ship would have been compelled to sail without a generator and using oil lights.

Conclusion.

While the adoption of the 125-volt system is a long step in the right direction, it must be clearly borne in mind that this is not sufficient in itself to ensure that all the advantages will be secured which might be derived from this circumstance. Having adopted a commercial voltage, the navy must now eliminate from its specifications all special features which are not essential to the efficient operation of its electrical apparatus on board ship. It will be only by so doing that all the possible benefits of the change will be secured.

In closing it may be remarked that the success in quickly fitting out the *Ajax* mentioned above was due quite as much to the fact that the material purchased was thoroughly commercial in other respects as to the fact that a commercial voltage had been adopted.

A paper presented at the 176th Meeting of the American Institute of Electrical Engineers, at New York May 28th, 1902.

ELECTRICITY IN PERMANENT SEACOAST DEFENSES.

BY MAJOR GEORGE W. GOETHALS, U. S. A.

In order to understand the history and conditions governing the installation of electrical plants for use in connection with seacoast defenses, which is the subject of this paper, a few remarks explaining the actual conditions of a military post on the coast may not be amiss. Along our seacoast there are certain harbors from which, for strategic reasons, it is desired to exclude an enemy by means of properly constructed defenses. To accomplish this object, sites are procured from which command of the approaching channels may be had, and these sites are designated as forts or posts. On these sites are scattered the guns of various calibre, either singly or, more frequently, in groups of two, three, etc., as the extent of the site and the proper command of the channel may require.

An emplacement is understood to mean that part of a battery occupied by one gun, including the platform on which the gun is mounted, its magazine, shell-rooms, storerooms, offices, etc. Two or more emplacements constitute a battery. A fort is an aggregation of batteries, together with barracks, hospitals, quarters, storehouses, etc., and such buildings as are needed for the administration, operation and care of the batteries. Therefore, "Fort Wadsworth," for instance, applies to the entire reservation on which are several batteries and the necessary buildings for the garrison. To the Corps of Engineers is entrusted the construction of the emplacements and batteries, together with the installation of such power as may be needed to light them and to operate the motors connected with the ammunition service and the maneuvering of the guns. On their completion, the works of defense are transferred to the artillery branch of the service for operation and care.

In the earlier emplacements and batteries no provision was made for using electricity, not because the desirability of its use was not considered or understood, but from a desire to mount as many guns at various localities as possible, using the very limited appropriations received from year to year for this purpose rather than for purposes not absolutely necessary. As the works for defense advanced, small available balances were expended for lighting batteries already completed, or nearly so. Where the emplacements offered available room, such plants were installed in the battery; when such was not the case, small power-houses were constructed near the batteries for the purpose, and in some cases two or more batteries were lighted from the same plant, but this was rather unusual. Such plants were necessarily small, operated in some cases by steam power, when the smoke stack or steam escapement could give no possible clue to an enemy, but in the majority of cases they were operated by a gas engine. The lamps ranged in voltage from 80 to 110; generators, switchboards, etc., were arranged to suit the particular conditions at the battery under consideration and the money available. These plants were provided with a small storage battery as a reserve, to obviate the necessity of operating the entire plant every time the lights were desired, and in their entirety were so simple that an intelligent enlisted man was able to operate them.

The number of such plants installed was comparatively small, and the subject had been regarded as rather in an experimental stage, but sufficient experience had been had to warrant a serious consideration of the subject, with a view to applying electricity in all gun batteries for furnishing light and also for supplying power to raise the projectiles of the larger calibred guns from the level of the magazines or shot-rooms to the gun platforms. The desirability of uniformity in the plants was also apparent and to secure this as far as practicable, a board of engineer officers, consisting of Major Smith S. Leach, Lieut. J. B. Cavanaugh and Lieut. R. R. Raymond, all of whom had had experience in installing and operating plants in connection with fortifications, was convened for the purpose of considering the application of electricity for furnishing light and power to the batteries, and to make such recommendations as would accomplish the desired results, and at the same time to prepare specifications which could be followed in all future work. Thus far, it must be understood, the emplacement lighting and the power for

operating the ammunition hoists were alone considered, so that the conditions that such installations were designed to meet were: intermittent service, inexpert and non-continuous attendance, and exposure of the generator and switchboard apparatus to the moisture of the emplacements, since complete protection against all kinds of fire from a hostile fleet was advisable.

While centralization was considered desirable, it was not to be carried beyond the limits within which the standard voltages of all parts of the system could be maintained with a reasonable expenditure of copper, so at some posts where the batteries were considerable distances apart there might be two or more plants. The power-houses were to be in one of the batteries, if room were available, or in a bomb-proof structure built for the purpose and to be divided: for steam plants, into rooms for boilers, for engines and generators, and for accumulators; for oil engines, into rooms for engine and dynamo, for cooling tanks,if required, and for accumulators. The oil engine has given considerable trouble where used, because the engine did not accommodate itself quickly to fluctuations in the load, and on account of the impossibility of securing men in the immediate vicinity competent to take care of the engine and to make repairs in case of an accident or injury. Consequently, the steam plant was advocated.

The considerations which guided this board in the mechanical and electrical details were stated as follows:

1. The greatest probability that the plant would be ready for service at any future time, having in view simplicity of design and freedom from deterioration.
2. Uniformity of methods of operation and of methods of construction, so far as the latter involved the former.
3. Economy of operation.
4. Economy of first cost.
5. High commercial efficiency.

A vertical boiler and a generating set, consisting of a vertical high-speed engine direct-connected to a direct current, compound-wound, multipolar dynamo, the engine and dynamo resting on a common bed-plate, were recommended for all future installations. Reserves were recommended in the form of acumulators and were to be installed in all batteries, of 6-inch calibre guns or greater, their capacity to be determined by the lighting load only, without reference to the power load represented by motor-driven machinery, as the hand-operating

devices were in themselves a satisfactory reserve. Reserves for the batteries to the smaller guns were to be made portable. The reserves were to be distributed so that a single accident or injury would not disable both the generator and the reserves at the same time, and also in order that any injury to outside wiring leads to the central generating plant could not disable the reserves. Under these conditions, the reserves were distributed among the various batteries, the reserve for each battery being sufficient in capacity for the lighting load of the particular battery with which it was connected.

The accumulators were arranged so that they could be divided into two equal parts for charging in parallel and discharging in series, the voltage during both charge and discharge being regulated by means of rheostats. This arrangement has many advantages for fortification work. No change is required in the normal voltage at the bus-bars, thus enabling the lights and motors to be operated while the accumulator is being charged, and in the central plant, all the accumulators may be charged at their normal rates, irrespective of their condition as to charge, without interfering with any of the motors or lights throughout the installation. The generators may be of a standard commercial type, a special winding for raising the voltage during the charging of the accumulator not being required. The danger of discharging the accumulator through the generator is reduced to a minimum, since the counter electro-motive force due to the accumulator in parallel is much below the normal voltage of the generator. The greatest disadvantage of this method of charging is its low efficiency, which, while a serious objection in commercial practice, is of less importance in fortification work. Glass jars were advocated as containers for the electrolyte, and these were to be placed on cushions made of hard rubber, so as to distribute the weight and prevent strains due to changes in temperature.

While uniformity was considered desirable in all parts of the installation, the board was of the opinion that the identical arrangement and operation of all switchboards was so very desirable that it should be insisted upon in all future constructions. The chief requirements are a dry and clean situation, high insulation and protective appliances, and the reduction of the number of manipulations required to the lowest possible limit. The board presented and recommended for adoption standard panels for generators and accumulators. A drawing of this

type is appended in Figs. 1 and 2. For each installation there are required one generator panel and as many accumulator panels as there are reserves, the generator panel to be installed in the power room and the accumulator panels with the reserves. The generator panel is provided, in addition to the usual measuring instruments, feeder switches, etc., with cut-outs and fuses to protect the generator from over loads. The cut-outs are designed to open with 25% overload and the fuses to blow with 50% overload. The magnetic overload protection is in two

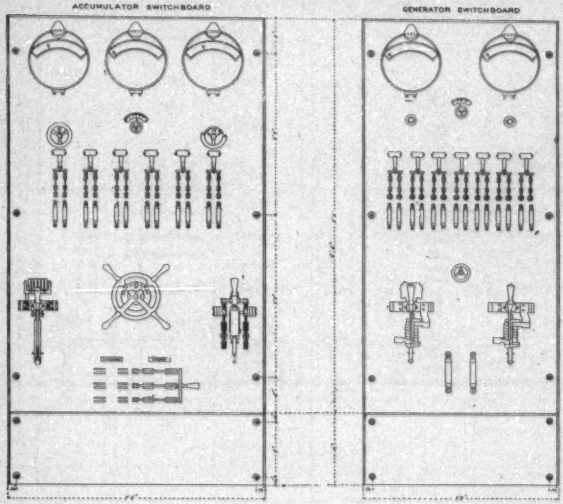


FIG. 1.

separate instruments not to be operated simultaneously, so that one is free to act during the closing of a circuit, should a short-circuit exist. One of the cut-outs is provided with an underload attachment, to protect the dynamo from the discharge of the accumulators. The accumulator panel is provided with a triple-pole, double-throw switch, making all the connections for charging or discharging the battery, as is desired, and also to protect the generator on discharge from short-circuit by breaking one pole of its leads. Both ammeters are double-reading and on

charge each records the current in one-half the battery; on discharge they are in series and both record the rate of discharge. The pilot lamps are connected across the bus-bars, and will not light up when the triple-pole switch is in position "Charge," unless the generator is in operation ready to charge the accumulator.

In this system, a circuit of 110 volts is adopted for the lamps and motors, and the maximum drop in the installation of any single-gun battery is to be restricted to two volts, if practicable,

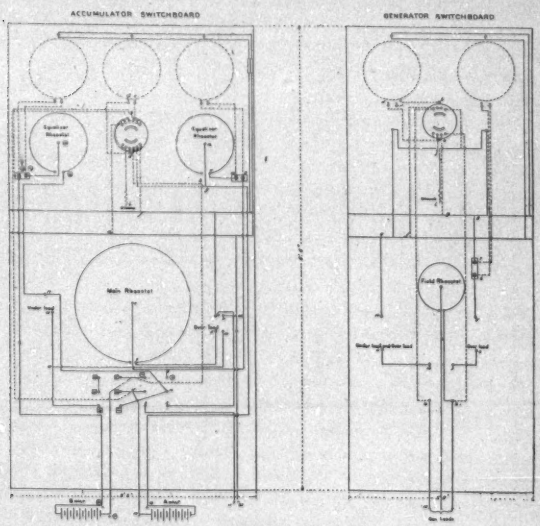


FIG. 2.

thus giving a normal voltage of 112 at the bus-bars of the accumulator panel, from which the lights and motors are supplied. In the central plant, the voltage of the generator is limited to 115 volts, if practicable, to minimize the fluctuations of voltage at the accumulator bus-bars due to variations in loads, and the conductors from the central plant to the several batteries are so proportioned as to give the same drop from the generator to each of the accumulator panels when carrying the normal loads.

Overhead wires were advocated wherever they could be obscured from the enemy's view, and for this purpose ordinary

weather-proof wire with high grade insulators on stout poles was advocated. If the conditions of the ground were such that an aerial line could not be concealed from view, the cables were to be placed underground, carried in well-laid vitrified conduit at a depth sufficient to give ample cover. The specifications which resulted and which form a part of the report of this board will be found in Professional Papers No. 27, Corps of Engineers. They have been regarded as rather severe in their

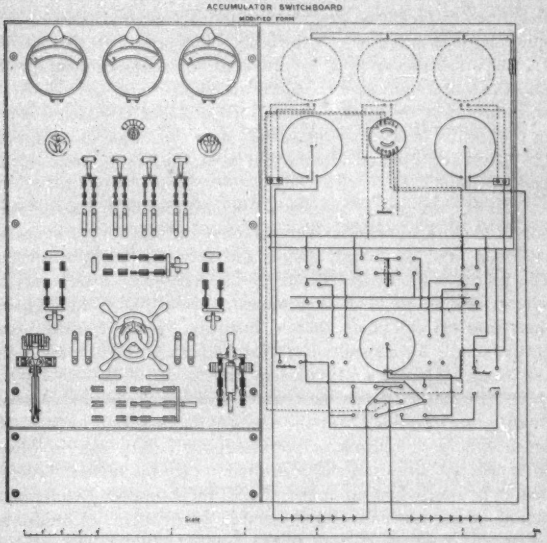


FIG. 3.

requirements as to boiler, generators, wire, etc., but in work of this character it is absolutely necessary that the best practicable types of machines be installed, for, as competition is required by law, it is better that the requirements be severe than that an inferior plant be forced for acceptance with the liability of failure at a most critical time.

Shortly after the issue of the report of this board and the standard specifications, combined naval and land maneuvers were undertaken at Narragansett Bay, R. I. The importance of the

searchlight up to this time had not been fully appreciated, and though they were provided at the various defenses for the purpose of guarding the mine fields against a night attack, their use in connection with the batteries had received but little consideration. As a result of these maneuvers, the necessity of searchlights as an adjunct of defense was established and another factor was introduced. Future plants would have to furnish sufficient power not only for emplacement work, but also for searchlights, and this addition required an increase in the capacity of the machines to meet the greater demand. The conditions and requirements as laid down by the board remained as yet unchanged. In the two services now to be provided, the emplacement service and the searchlight service, there was this difference: electricity was absolutely necessary for the operation of the latter, while in the former it was not essential, since lanterns could supply the lights and manual labor could work the ammunition hoists and the guns

Thus far, the plants installed were used for emplacement work only, the storage batteries were charged and discharged at stated intervals and, as noted above, the service was intermittent. The plants were in the hands of the Artillery Corps, and the officers desired to avail themselves of these plants for lighting their quarters and posts, thereby insuring, by their constant use, better care. As a result, the War Department authorized the use of such plants, if of sufficient size to do this work, by the Quartermaster's Department when authorized by the Chief of Engineers, " provided that the needs of defense shall have precedence over post lighting or power supply in any case in which both uses are simultaneously desired." It was further ordered that in future, when funds permitted, the Engineer Department should construct such ducts, service wires, etc.. as might be necessary to deliver current to the buildings and to the exterior lights. The Quartermaster's Department was to wire the buildings, furnish the exterior lamps and to supply all plants used for post lighting with the necessary materials and funds for their repair and preservation. A third service was thereby imposed.

The Quartermaster's Department and the Artillery Corps desired for such lighting of posts low potential service throughout, mainly on the ground of simplicity and because of the character of labor that was to be employed in operating the plant; a centrally-located plant, due consideration being had to protec-

tion against hostile fire, accessibility for supplies, etc; that the plant be sufficiently large for doing all the work connected with the fortifications, and alternately for post and building lighting (in other words, the larger of these two services would govern the size, assuming direct current machines to be used); that the generator unit be sub-divided, thereby providing two engines and generators, so that in case of injury to either half the other would be available for the more necessary purposes; and, finally, that all wires be underground rather than overhead, in order to reduce the cost of maintenance. With these additional services, the original conditions were changed, the whole subject required consideration anew and the matter was referred by the Chief of Engineers to a board of officers of the Corps of Engineers consisting of Major Smith S. Leach, Major S. W. Roessler and the writer, to consider the entire subject from the new standpoint, including the wishes of the Quartermaster's Department and of the Artillery Corps in the matter, and to modify the requirements as originally provided for fortification purposes as the new services necessitated.

The fullest possible electrical demand at any military post will embrace, therefore:

1. Searchlight service.
2. Emplacement service.
3. Garrison service.

And the engineer officer must design his plant for these three services.

The searchlight service requires current for a number of searchlights to be used in conjunction with the batteries placed in their vicinity. The number and size of these lights for any particular post is definitely known in advance.

The fortification service requires current for lights in the various rooms of each emplacement, on each gun-platform, in the range-finding stations; current for power to work the motors for ammunition service, for traversing, elevating and depressing the guns and to operate a machine shop for minor repairs to the guns and carriages, and, finally, current for the recently adopted telautograph system connecting the range-finder stations with each other and with their respective batteries.

The garrison service requires current for lighting the grounds and buildings, including barracks, quarters, hospitals, storehouses, etc., which may be in close proximity to the batteries or

at considerable distance from them, depending on the size and configuration of the reservation.

From an examination of a number of proposed projects, it is ascertained that the first and second of these services will, on the average, be of the same kilowattage or nearly so, and that the third will rarely exceed the same amount, in the majority of cases being less. The nature of the third service is not the same as the other two. The searchlights are to be operated only at night and can be operated only by electricity, and their continuous and perfect operation is a paramount exigency of the defense. Partial efficiency does not produce partial results. If the searchlights do not operate perfectly and continuously, they are of comparatively little use. The accumulator reserve alone is not satisfactory for this service, since a battery of reasonable size cannot supply the searchlights for more than eight hours, which might not suffice for making repairs. Should any mishap occur to the generating plant, it is probable that the searchlights would be put out of action. On account of these considerations, the board recommended that the generating plant, so far as the kilowattage was concerned, should be mechanically duplicated, boiler, engines and dynamos and,as a mechanical reserve is not always instantly available, in order that the searchlight might be kept in operation while the duplicate plant was being started,that the accumulator reserve should be made available for this purpose. It will be used a comparatively short time and an unusual size will not be required. The emplacement service will be required only while the guns are in action actually, or similated in drill. At such times, this is a convenience only, not a necessity, since non-electrical reserves are provided for handling ammunition and may also be arranged for lighting. An accumulator reserve is practicable for this service, since a battery of reasonable size may be made to supply the more urgent needs of the emplacements for several days, and its instantaneous availability and its ease of subdivision are advantages over a mechanical reserve. Both searchlight and emplacement services are on a non-commercial basis, and economy of operation is a consideration of comparatively little weight.

The garrison service will be required during the hours of commercial illumination and will be of constant service during peace, probably discontinued during war. Garrison service considered alone should have the same weight given to econ-

omy of operation as in commercial lighting, and the use of reserves, accumulator or mechanical, should be considered mainly from the standpoint of use. The conditions are changed when this service is connected with the other two in the same installation. Both mechanical and accumulator reserves are required for the emplacement and searchlight services, and they are available for the garrison service, their use in that service depending so far as may be upon economy of operation. Current used from an accumulator is very costly, and when the variations of load, cost of fuel and local conditions are known, a simple computation will show whether it is desirable to supply current in the hours of light load from the accumulator or to run the generator during the full hours of service.

For supplying these three services, the central power station is now adopted, its location depending on local conditions, and it must be so constructed as to be proof against hostile fire. The vertical boiler, in most cases, must give way to a more efficient type; horizontal engines must in some cases replace the vertical and they must be compound or condensing, depending on the local conditions; and the direct connection of the engine and generator, while still preferable, is not essential. The minimum capacity of the generating plant should be twice the normal demand of the searchlights, and, as stated above, should be in two equal, wholly independent parts, either or both of which may be subdivided as the local conditions indicate. Connections should be made to permit either part to supply the searchlights, giving complete mechanical duplication for this service by dispensing with the others.

Great difficulties will at times be encountered in attempting to furnish adequate garrison service at reasonable cost by using direct current. This is also true when in any particular case two forts are sufficiently near each other to warrant the consideration of one plant doing the work for both, and these difficulties are to be overcome by the introduction of alternating current for the garrison service. The condition is imposed that if alternating current be adopted for garrison service, it shall be supplied from the same plant that supplies the emplacement and searchlight services, which require direct current.

The method suggested by the Board for consideration in the accomplishment of this result is by introducing a motor generator into the garrison feeders, taking direct current from the generator and delivering alternating current to the line at 1,000 or 2,000

volts, according to the distance of the transmission. Static transformers, according to the usual commercial practice, will reduce the voltage to 110 for delivery to the lamps. The objections to this method are the cost and maintenance of an additional machine, the motor-generator, and the liability of derangement of the lighting system by irregularity or failure in its operation. The losses in the system will be those of the motor-generator, plus the line losses, plus the transformer losses at the other end.

The same result, the supplying of direct and alternating current from the same plant, may be reached by the employment of a rotary converter instead of a motor generator. This machine has but one set of coils, takes the direct current from the generator at 110 volts and delivers alternating current at 77 volts, with very slight losses. A special static transformer will be required with the proper ratio to raise the voltage to that determined upon for the line, and standard static transformers at the other end to reduce the voltage to 110 for delivery at the lamps. The losses in such a combination will be that of the converter, very small, plus the losses in the line and two static transformers, plus the losses allowed in the line. The objection to an additional machine applies here also.

A third method was investigated as far as was possible in the time at the Board's disposal. It depends upon the employment of the same machine as the second method, but it is used in a different way. The rotary converter, instead of receiving and being driven by a direct current at 110 volts and delivering alternating current at 77 volts, may itself be driven by a prime mover, in which case it becomes an A. C. D. C. generator, giving direct current from the commutator at 110 and alternating current from the collector rings at 77 volts. Constructive conditions appear to demand that these machines shall be driven at a higher rate of speed than is possible with direct connection, and if this method be adopted, belt-driving follows as a necessary consequence, but this is not considered a serious objection under the circumstances of the new installation. With an A. C. D. C. generator, a special static transformer will be required to step up and standard ones to step down, as in the second method. In this system, one machine is saved and losses will be about ten per cent. less than in the second method. The belt connection will require considerably more floor space than the engine type, and the only open question in this method is the effect of varying

loads on the direct side upon the regulation of the alternating side, but as in the installations contemplated, the combined load will rarely, if ever, occur, this question for fortification purposes becomes of secondary importance.

The use of boosters where low-tension direct current is to be transmitted over a considerable distance, is worthy of consideration; not only is this true in connection with the garrison lighting, but also in charging the larger accumulators that the new conditions require. The accumulator reserves must be increased in size and be made of sufficient capacity to supply the searchlight service for *one hour* at a non-destructive rate of discharge, which the Board experimentally determined might be taken at four times the normal rate of discharge, or to supply the lighting load of the emplacement for eight hours at normal rate. The one of these conditions which called for the larger accumulator should determine the minimum size.

Recent experience in heavy mortar firing leads to the conclusion that the largest glass jars now made will be uninjured by concussion and may be safely used. So long as glass receptacles can be obtained in the market, they are to be preferred to any others, so as to facilitate the inspection of the elements. The cells should be arranged as far as possible in single tiers vertically and in single rows horizontally. While this open arrangement is of distinct value and advantage, it is not sufficiently desirable to demand the construction of a larger room, if a smaller one already built is available.

There appeared to be no good reason for changing the system on which the switchboards had been worked out. The proposed type of plant is to consist of duplicate generators for distribution to searchlights and garrison buildings, in addition to emplacements. The two generators are supposed to be equal in capacity to the normal load, with overload capacity sufficient to take care of the variations, the second generator being provided as a mechanical reserve. The generators are under no circumstances to be operated in parallel, since each being the mechanical reserve for the other, they should not be exposed to a common danger; but, with their circuits kept separate, arrangements are proposed for working them in combination in case the demand exceeds the capacity of one, each, when so working, to take care of a distinctive part of the load. What is required, therefore, is, first—so to modify the generator switchboard that it shall permit either of the generators to supply current to several of

the accumulator panels, permit one to supply certain feeders, and the other to supply certain others, while making it impossible to throw them both simultaneously on to the same line; and second—to modify the accumulator panels as may be necessary to provide for such of the requirements of the garrison and searchlight services as are not met by the type previously adopted. The restriction as to parallel working applies only to such units as are duplicated for reserves; if one of these be again

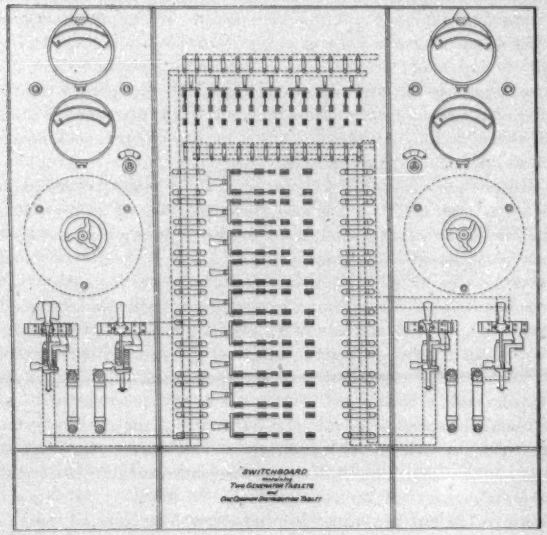


FIG. 4.

divided for economy of operation, or for other reason, the two parts may be operated in parallel on a common panel.

It is proposed to provide each half of the generating plant with its own panel, carrying the measuring and indicating instruments and safety devices required for its operation, and about one-half the feeder switches. The two panels set side by side will form the generator switchboard. The bus-bars will be placed sufficiently out of alignment, so that each pair can be extended across the other panel, connecting with the distributing switches thereon, but not with any other apparatus. The

feeder switches will be double-pole, double-throw to operate on either set of busses. They should be provided at the hinge with a spring holding them firmly in the neutral position, to permit of mounting them vertically instead of horizontally, which will greatly reduce the space required and simplify the connections. A single motion will throw any feeder on to either of the generators, or from one to the other. Either generator may be operated on any circuit, or on all of them, and both may be operated together, each supplying any desired circuits, but it is

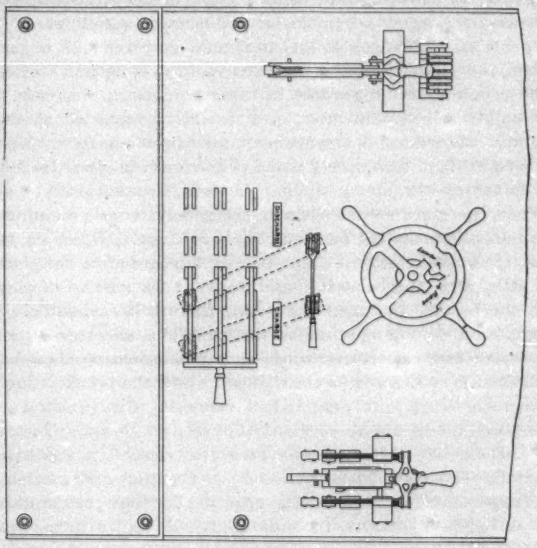


FIG. 5.

not possible to connect the two generators on the same circuit. A diagram showing two such panels is appended, Fig. 4.

Where the number of circuits to be operated is so large that the generator panels do not afford convenient space for mounting the feeder switches, the latter may be placed on a separate distribution panel, and the generator panel be reduced to the measuring instruments, a single switch connecting it with the distribution panel. This arrangement is also shown on the accompanying drawing, Fig. 5.

Two cases not covered by the type accumulator panel must be provided for. The first is to operate the searchlight from the generator while the accumulator is discharging. This may be done by using a double-throw switch for the searchlight circuit, connecting with the busses in one position, and the other with terminals branched from the generator leads at their entrance on to the board. By such an arrangement it will be found possible in many cases of long transmissions greatly to reduce the size of feeders using the accumulator exclusively for supplying lights, and throwing into line a portion of the large drop which occurs in charging accumulators and running searchlights. The second case will arise if the maximum garrison load is greater than the capacity of the generators and it is desired to put on the accumulator in parallel to take the peak. This case, it is thought, will seldom arise, and should be regarded as exceptional. The desired arrangement may be made by connecting the right-hand terminals 2 and 3 of the lower blade of the triple-pole switch through a single-pole switch conveniently placed. When the extra switch is open, the generator and accumulator cannot be put on the busses at the same time. When the extra switch is closed and the triple-pole switch thrown to the position of discharge, the generator and accumulator will be in parallel on the busses, and their joint capacity will be available. The regulation of voltages under these circumstances will require constant and expert attention, and such attention should give reasonable security from the dangers which the break 2–3 in the generator leads was designed to obviate. Fig. 3 shows the proposed modifications of the type panels.

Considerable difficulty has been experienced in the use of metallic rheostats from corrosion, overheating and mechanical derangements, and the Board suggested for the consideration of local engineer officers the advisability of substituting water rheostats for metallic ones for handling large main currents. The principal requisites of a water rheostat are non-corrosive plates, preferably carbon, with closely regulated motion to control both the distance from each other and their immersion in the liquid, which should be pure water slightly acidulated. The degree of acidulation will exercise a marked influence in the resistance of the rheostat, and may be utilized with advantage in that respect, Such a rheostat should be placed where fumes can escape easily to the air and the material for its replenishment should be kept close at hand, available for instant use, with an

arrangement to operate it from the usual position at the switchboard. A water rheostat well constructed and in good working order will give closer regulation than can be obtained from metallic resistances arranged in steps.

The original specifications required for all cable laid underground, conductors of soft annealed copper 98% pure, covered by an approved insulation 5/32″ thick and protected by a lead sheating ⅛″ thick, with a saturated fibrous covering over the lead. The insulation must be sufficient to stand a potential of 3,500 volts intermittently applied, and the resistance must not be less than 1,000 megohms per mile, when tested after twenty-four hours in sea water and after one minute's electrification. With the larger size of cable that is made necessary by the extension of the service, these resistances cannot be obtained with the specified insulations and the new conditions can be more satisfactorily met by the use of the standards adopted in commercial practice, especially for battery purposes and searchlight load, and the Board has so recommended. Aerial wires are also hereafter to conform to commercial practice rather than that required by the stand specifications.

In general, the use of aerial mains and branches for garrison lighting, in conformity with the prevailing practice of low potential current distribution in all but the largest cities, is regarded as feasible in cases where underground mains would be unduly expensive. Their exposure to rock splinters, shrapnel, rapid-fire and machine-gun projectiles, is not regarded as a serious objection to their use in this service, since any severed mains, being easily accessible, can be repaired if necessary. Nor is the exposure of such lines to the view of the enemy regarded as a weighty objection, except in so far as the lines and poles might disclose the position of the power-house, the location of which would otherwise remain undetected. This difficulty is easily overcome by the use of underground conduits in the immediate vicinity of the generating station. Mains for searchlights, motors and emplacement lighting should be placed in underground conduits wherever they are not concealed from view of the enemy, or where concealed aerial lines would not be reasonably well protected by intervening obstacles from shrapnel, rock splinters and machine and rapid-fire projectiles. The depth at which the conduits should be placed to secure the desired protection depends upon the nature of the ground and the configuration of its surface, and cannot, therefore, be defined

in specific terms. In general, it may be said that the depths of the conduits should be greater on ground sloping downward toward the enemy than on level ground, and greater on level ground than on a surface sloping downward toward the rear. In the horizontal area within which the heavy projectiles against a fort may be supposed to fall, the depth of the mains should, if possible, be greater than the probable vertical penetration of the heaviest projectiles, but they can safely be placed at a less depth along stretches of ground against which no heavy fire is likely to be directed. Possible interruption of garrison lighting over aerial mains by storms is believed to be less likely to occur than in commercial plants in the same locality, where mains are usually of much greater length than those required on a military reservation.

In the matter of lamps, the incandescent type is used for fortification lighting, and care is taken to secure lamps that will give a suitable distribution of light in all directions, which is not done by all lamps on the market. For the lighting of the grounds, the Quartermaster's Department has adopted and installed incandescent arc lights requiring 480 watts each.

The motors used for ammunition service are to be of the completely enclosed type, practically moisture and dust proof; to conform to the adopted voltage, and must be so arranged as to be easily and quickly detached from the hoists, permitting operation by hand in case of accident; otherwise, this part of the service is in an experimental stage. Trial is being made in some of the defenses about New York with worm gearing and spur gearing, and a special type is being made by the Elicott Machine Company of Baltimore to do similar work in Boston. Absolutely safe action in raising and, more particularly, in lowering, projectiles is very essential. These motors are supplied and installed by the Engineer Department. The Ordnance Department has contracted for motors to traverse, elevate and lower the guns, and two designs are to have a trial before a standard type is finally adopted. One is being constructed by the General Electric Company and the other by the Sprague Electric Company. Descriptions of the details of motors for this service are not taken up here, for it is understood that these will be explained and discussed in other papers.

From what precedes, it is readily seen that the conditions under which the first Board worked out its problem are materially changed. Intermittent service is replaced by continuous

service owing to the introduction of garrison lighting. Inexpert and non-continuous attendance, under present conditions, can no longer obtain, much as it may be desired by the Quartermaster's Department. Excessive moisture, due to condensation, is no longer to be dreaded because of the heat given by the generating plant. Simplicity of design and uniformity between the plants at the different stations, so very desirable, if not essential, since from the nature of the service army officers must be in control and changes of station from time to time seem necessary, is no longer possible, and every engineer officer in charge of fortifications must work out his own problem to suit his own local conditions, adhering to direct current throughout, if economic considerations permit, since those who are to have charge and operate the plant so desire.

Starting with the desire to light the emplacements, the application of electricity in connection with the permanent defenses has grown so rapidly and is applied for so many different purposes that it is difficult to foretell where the end will be. To the question of simple lighting is added the problem of furnishing power for the ammunition service, as a labor-saving device only, since ammunition can be supplied to the gun much more rapidly by hand than the gun service requires. Next comes the garrison service. Then we learn that motors are to be introduced for traversing, elevating and lowering the gun, machine shops to be built and operated by electricity for the use of the ordnance experts, telautograph systems to be installed by the Signal Corps for transmitting ranges and azimuths rapidly to the guns and, finally, it is learned that arrangements are to be made for firing the guns from the battery commander's station by electricity, current for all of which purposes is to be obtained from the central plant installed by the Engineer Department.

If, in the future, this advance be continued, it may not be long before even the transfer of ammunition will be made by electricity from the magazines and shot-rooms to the gun direct and the gun loaded and laid by the same means. There will then remain only the proper control in the battery commander's station to have all the work done without the aid of the enlisted man, the latter being needed only in case of a breakdown to any part of the system; in short, all that we will have to do will be to press the button, the electrical engineers and manufacturers having attended to all the rest.

A paper presented at the 166th Meeting of the American Institute of Electrical Engineers, at New York, May 28th, 1902.

SUBMARINE CABLE TESTING IN THE SIGNAL CORPS, U. S. ARMY.

BY TOWNSEND WOLCOTT

There is much in cable testing that is old. In fact any one who for the first time reads Clark and Sabine's "Electrical Tables and Formulæ" and compares it with modern practice, will find that a great deal of information passes for new because it appears in modern books. This book was published in 1871, but it starts out with a table of dimensional formulæ, and then defines the practical units. The ohm is given as the practical unit of resistance, the volt as the unit of e. m. f., and the farad, or rather, microfarad, as the unit of capacity. The only things that would look strange in a modern book are the weber as the unit of quantity, and the metre, instead of the centimetre, as the fundamental unit of length. The book then goes on to discuss most of the questions that are considered in practical cable testing to-day.

On the other hand, I do not mean to say that there is nothing new in cable testing, for if this were so there would be no call for a paper on the subject. One of the chief features of modern cable testing is the preliminary breakdown test at a high voltage. This is followed by the time-honored measurements of electrostatic capacity, insulation resistance and conductor resistance, which complete the electrical testing. The armor wire is submitted to mechanical tests and a chemical test for galvanizing. These are the regular tests, and although the other materials entering into the cable may be subjected to tests, their quality may usually be determined pretty well by simple inspection.

The Signal Corps of the United States Army has charge of the greater part of the telephone and telegraph lines, including the submarine connections, owned by the army. Before the war with Spain the submarine cables belonging to the army were all short lengths connecting points on the coast and islands near the coast, but during and since the war the number of these cables has been considerably increased, while the acquisition of the Philippines by the United States has rendered necessary the laying of many cables, aggregating hundreds of miles, with some individual cables of considerable length. There have also been two moderately long cables laid in Alaska. These cables are all insulated with rubber compound, and were all manufactured within one hundred miles of New York City. In view of these facts, this paper treats only of rubber cable testing.

The greater part of the Signal Corps cable is made with a standard size of core; namely, a strand of seven No. 21 B. & S. G. copper wires, well tinned to prevent the sulphur in the rubber from attacking the copper, insulated first with pure Para rubber to the thickness of 1/64″, then with 40% compound to an outside diameter of 9/32″. This core is then taped with rubber saturated cloth tape, after which it is usually subjected to the first electrical test although this test is sometimes applied before taping. If this test is satisfactorily passed, the core is served with jute, armored and served with jute again, the outer jute being saturated with asphalt compound to protect the armor wire from the corrosive action of the sea water. The finished cable is then subjected to the second electrical test, which being satisfactorily passed the cable is accepted.

The core is usually made in lengths of approximately one mile each, which is about the greatest length that can be conveniently vulcanized, although some manufacturers can vulcanize five miles in one piece. These one-mile pieces are sometimes subjected to the first electrical test singly, and sometimes they are joined into five-mile lengths before testing. The piece of core, whether one or five miles in length, is placed in a tank of water with the ends hanging out, and there left for a number of hours at, as nearly as possible, a constant temperature. Sometimes the core is on reels, but the preferable way is to lay it loosely in the tank, doubling it back and forth upon itself, so that there is plenty of room for the water to percolate between the parts of the core, thus ensuring that the core shall eventually reach the same temperature as the water.

After 24 hours' immersion the breakdown test is applied. This consists, for the standard sized core, of 5,000 volts alternating, usually with 20 to 30 cycles, though sometimes as high as 130. The object of this test is not so much to see if the general quality of the insulation is good, as to search out any accidental impurities. If the insulation be sound, this size of core cannot be perforated by 5,000, or even 10,000 volts, but in working hundreds of pounds of rubber compound it is impossible not to have an occasional speck of dirt get in, and if this speck of foreign matter be so situated as to reduce materially the virtual thickness of the insulating wall, the high voltage finds the weak spot with unerring certainty and perforates the wall at that point. It is customary to apply the high voltage for five minutes, but in every case that has come under my notice, the perforation has occurred in the first few seconds after the voltage was applied. My own opinion is that the perforation is practically instantaneous, but it takes several seconds for enough gas bubbles to collect to give a visible indication. In applying the test, one lead from the transformer is connected to the copper strand and the other lead is immersed in the water in the tank. The core so connected acts as a condenser, with the copper strand and the water as the plates. The specifications for the standard core are .4 of a microfarad per statute mile as the maximum allowed. A five-mile piece, therefore, has a capacity of two microfarads or less. Neglecting the effect of conductor resistance, this capacity at 5000 volts and 30 cycles should take a current of something less than two amperes. As a matter of fact the current is usually 1.6 amperes, which means eight kilowatts apparent energy. The power factor is, of course, very small, probably less than 1%, but is subject to considerable change on apparently slight provocation. For example, in a case where the transformer secondary was wound in four sections, the apparent energy was eight kilowatts when all the sections were connected in parallel, and twelve kilowatts when one section was used alone. This may be due, as suggested by Mr. Steinmetz, to the fact that there is a large magnetic leakage in the transformer, and that the virtual ratio of transformation is different when all the secondary current is in one section, from what it is when the secondary current is divided among the four sections. As, in the case mentioned, the instruments were in the primary circuit, the secondary voltage may have been changed

without the fact being discovered. If this were the case it was not the power factor that was changed.

When a piece of core is perforated by the high voltage, the perforation at the worst is not much larger than a pin hole, and sometimes it is not discovered that the core has failed until the galvanometer test is applied. When the perforation is found the insulation immediately surrounding it is removed and the place re-insulated with rubber tape and re-vulcanized. After this, the high voltage test is applied again, and in almost every instance the ordeal is successfully passed, for almost always all the weak spots are blown out during the first test.

The core, having withstood the high voltage test, is next tested for capacity. The method used is the ordinary one in which the galvanometer is used ballistically and calibrated with a known capacity. It is best to use as low a voltage as possible in this test so as to minimize the absorption effect. If the throw be taken upon closing the circuit and again upon breaking it, the effect of absorption will be to increase the first throw and to diminish the second. In my experience there is very little difference in the two throws, and the throw upon breaking the circuit is quite as likely to be greater than the throw upon making, as it is to be less. This indicates that the effect of absorption is less than that of accidental disturbing causes. It is safe to say that ordinarily the absorption effect is negligible, considering the fact that under ordinary conditions in commercial cable testing the ballistic method is not susceptible of any great accuracy. I have frequently found that a throw of over 300 scale divisions could be repeated several times without varying a single division, and that it was the same on charge and discharge.

It is likely that the capacity of rubber insulation varies somewhat with the temperature, but we have no reliable data to that effect. The thing that has the most potent influence in changing the capacity is the high voltage test. It is a well-known fact among cable manufacturers that the application of the high voltage materially increases the capacity for some time after its application. It frequently happens that a piece of core, when tested for capacity immediately after the high voltage test, has a capacity too high to pass, but if left alone for a few hours, or at most over night, it will test all right. There is, so far as I know, no intelligent theory to account for this phenomenon, but it is a stubborn fact nevertheless. The

capacity will vary considerably with different lots of what purports to be the same rubber, made up into compound as nearly alike as it is possible to make it. Even the age of the crude rubber when it is manufactured makes a difference in the capacity.

The next test is for insulation resistance. This is measured in the usual manner, by passing the leakage current through a galvanometer that has been calibrated with a known resistance. Owing to the property of dielectric absorption (so called) the insulation resistance of most dielectrics is not a definite quantity unless the manner of measuring it is specified. For this reason it was agreed in the early days of cable manufacture, to take the deflection of the galvanometer at exactly one minute after the battery key is closed. This is the method described in Clark and Sabine's book, and it has been in use ever since. If the battery be left on for an indefinite time the deflection eventually reaches a steady value, which is the measure of the true leakage current. This value may be reached in a few minutes or it may take several hours. However, this true leakage current is ignored in ordinary commercial testing, and everything is based on the galvanometer reading at the end of one minute. The high voltage test has the effect of temporarily decreasing the insulation resistance and temperature has a most important effect, and it is chiefly for this reason that so much care is taken to have the temperature uniform and to ascertain accurately its value. It is of course necessary to know the temperature in order to ascertain the quality of the conductor, but the effect of temperature upon insulation resistance is even more important than upon copper resistance.

The resistance of all insulators decreases as the temperature rises and the law of variation is more or less approximately logarithmic. That is to say, as the temperature increases by equal increments, the resistance decreases by equal ratio-decrements. If, for example, a rise of temperature of 12° reduces the insulation resistance to one-half its original value, then a rise of 24° will reduce it to one-quarter of its original value. Clark and Sabine give, on page 115, a formula deduced by Bright and Clark from experiments on Persian Gulf core (1863). The formula is,

$$\log R = \log r - t \log 0.9399$$

where R = resistance at the higher temperature;

r = resistance at the lower temperature;

t = the difference of temperature in degrees F.

The resistance is measured, as already stated, exactly one minute after the e. m. f. is applied. It is evident that the minus sign in the right-hand member is an error, for log. 0.9399 is essentially negative, and the negative sign in the formula would make it positive. Maxwell, vol. I., page 503, third edition, writes C for the constant and puts the equation in the form

$$R = r\,C,$$

in which the error of the other formula is corrected. He gives the value of C as .8878 to .9. These values of the constant are for gutta-percha, with which we are not here concerned, but we are concerned with the general formula. Inasmuch as the law of temperature variation of the resistance is at least approximately logarithmic, it is evident that it may be plotted as a straight line on coördinate paper in which one of the coördinates is logarithmic and the other arithmetical. The annexed plate is ruled in this manner. On the lines passing through the upper left hand corner the decimal point of the coefficients should be moved one place to the right. In the lower right hand corner the decimal point should be moved one place to the left, with $\log 1 = 0$ in the middle and extending to $\log \sqrt{10}$ in one direction and $\log \sqrt{.1}$ in the other. This paper is not intended so much to plot actual resistances as the ratios of resistances at different temperatures. The specifications for insulation always read that the insulation shall be such and such a figure at some standard temperature. In case the insulation is measured at any other than the standard temperature, the important thing to know is what the resistance would be at the standard temperature. If the resistance of the given kind of insulation at the standard temperature be assumed as the unit, and the resistances at other temperatures reduced to this basis, the reciprocals of these values will be the required temperature coefficients. So long as the law of temperature variation is logarithmic these coefficients also plot as a straight line on the logarithmic coördinate paper. In dealing with a new insulation it is only necessary to measure the insulation resistance at two temperatures in order to construct a table of temperature coefficients. Take the ratio of these resistances and find the point of intersection of this number taken on the logarithmic coördinate, with the difference of temperatures taken on the arithmetical coördinate; then draw a straight line through this point and the origin, extending it to the limits of the paper in both directions. In the

Coefficients for Reducing Insulation Resistance at Different Temperatures to 60° Fahrenheit.

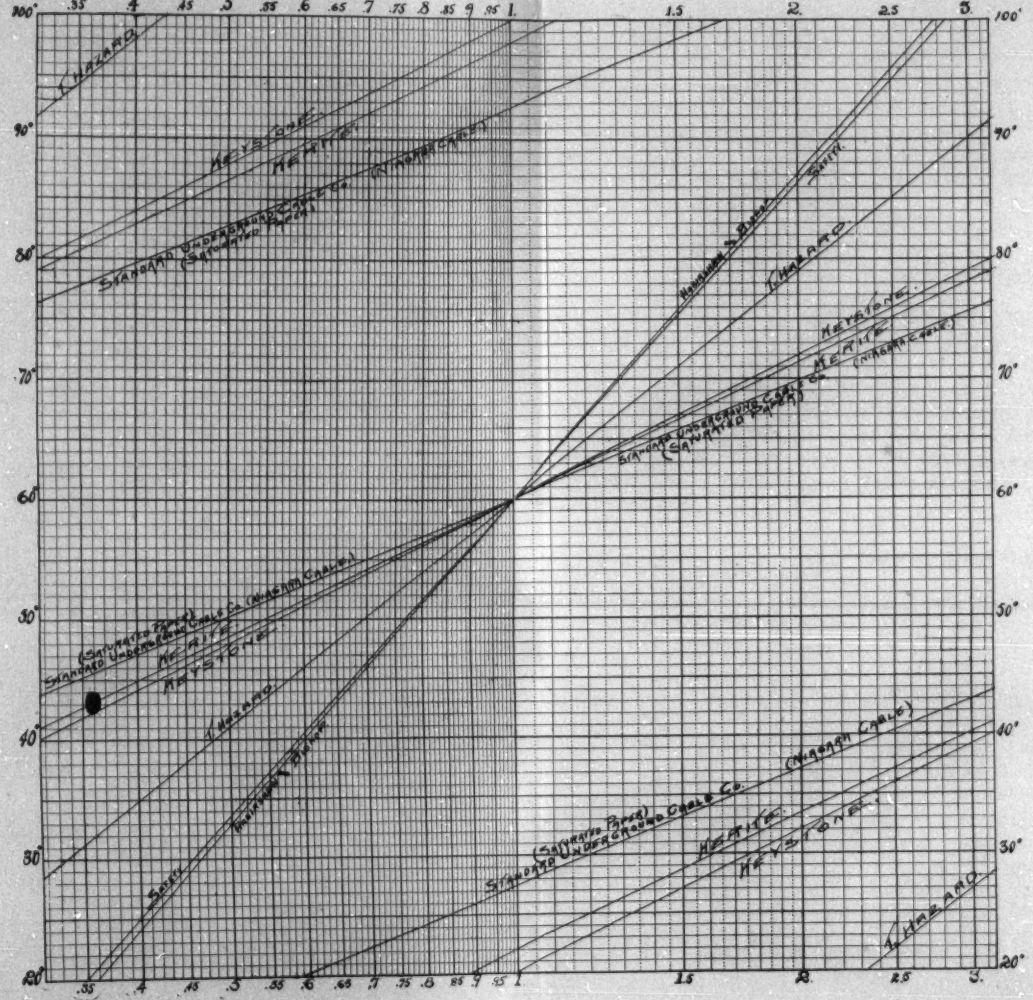

100°
90°
80°
70°
60°
50°
40°
30°
20°
.35
.4
.45
.5
.55
.6
.65
.7
.75
.8
.85
.9
.95
1.
1.5
2.
2.5
3.
Standard Underground Cable Co. (Saturated Paper)
Standard Underground Cable Co. (Saturated Paper)
Standard Underground Cable Co. (Saturated Paper)

plate the temperate coefficients of several different makes of insulation are plotted in this manner.

The simple logarithmic law is the first approximation to the true temperature law, and when accurate observations are not available it is always used and probably gives results as nearly correct as could be attained by any assumed law. When, however, a series of accurate observations is made, it is found that the temperature law contains another term. In Clark and Sabine. page 126, is given the formula

$$\log (R_t/R_{24}) = (0.06447 - 0.00017t)\,(24 - t)$$

where t = the temperature of observation;

R = the resistance at the temperature of observation:

R_{24} = the resistance at 24° Centigrade.

This formula was deduced by Willoughby Smith from experiments upon his own improved gutta-percha core. Generalizing this formula it becomes

$$\log (R_t/R_T) = (D - Ct)\,(T - t)$$

where R_T = the resistance at any standard temperature.

Mascart and Joubert, volume 2, page 754, give a formula credited to Foussereau Ann. de Chime et de Phys. (6) Vol. V., page 317, 1885, which applies to all known insulators. The formula is as follows:

$$\log R = A + Bt + Ct^2$$

where R is the resistance at the temperature t, and is therefore the same as R_t in the preceding formula:

A = the logarithm of the resistance at 0 Centigrade;

hence, $$A = \log R_T + D\,T.$$

D and B are related by the equation

$$D - C\,T = B.$$

It will thus be seen that the law expressed by the Foussereau equation is identical with that expressed by the Willoughby Smith equation. The constant, C, is usually small but not negligible. If it becomes negligible, the equation, of course, reduces to the simple logarithmic relation first given. For gutta-percha core, C is negative, but so far as my observation goes, it is positive for rubber componud cores. In two kinds of core where somewhat careful observations of temperature variation had been made, I found the formulæ best agreeing with the observations to be respectively, for Fahrenheit degrees,

(*a*) $\log\ (R_t/R_{60}) = (.00802488 + .000044619t)\ (60 - t)$ and

(*b*) $\log\ (R_t/R_{60}) = (.00845964 + .000286604t)\ (60 - t)$.

It will be seen that the value of the constant, C, in the second of the equations is much greater than in the first, so that not only is the temperature variation greater in the second formula, but also the departure from the simple logarithmic law. In both cases these formulæ agree much better with the observations than the simple logarithmic formula, but even in these circumstances there is a decided advantage in plotting the curves on the logarithmic paper, for when this is done the curvature is not very great in any case and it is much easier to detect an erratic observation.

Clark and Sabine give a table of temperature coefficients for Hooper core, which is a 40% rubber compound, based on the assumption that the resistance follows the simple logarithmic law and that the rise of 27° F. reduces the resistance to exactly one-half its value at the lower temperature. This is an approximation to the truth with most of the 40% compounds that I have tested, but it is not exactly true with any of which there have been accurate observations, and in the case of the compound to which the last formula applies it is widely different from the observed values. Nevertheless, these coefficients have been adopted as correct by more American manufacturers than any other one set.

One of the chief difficulties in making accurate insulation measurements is the uncertainty of the temperature. The ordinary thermometer will not at best show the temperature with any great accuracy, and supposing the thermometer to have any desired accuracy, the temperature is apt to vary different parts of the tank. Besides all this there is no certainty, even when the water all over the tank is at the same temperature, that the core throughout at the same is temperature as the water, unless the core has been immersed for a long time and the temperature of the water has been the same for several hours. It was long ago discovered by Mr. Hockin that gutta-percha does not attain its proper resistance at any given temperature until several hours after it has attained that temperature. The same is probably true of rubber compound, in which case care in the regulation of tank temperature is all the more imperative.

However, there is much less uncertainty with core than with finished cable, so after having observed the copper resistance in a piece of core and reduced it to the standard temperature, the resistance of the same copper conductor in the finished

cable will serve as a means of calculating the temperature of the cable. This in some cases is a valuable check on the observed temperature. The resistance of the conductor is measured in the usual manner with an ordinary Wheatstone bridge, and requires no further comment. The observed resistance is reduced to the standard temperature by the well known temperature coefficients for copper resistance.

Forty per cent. compound is made of 40% of pure Para gum, enough sulphur to vulcanize the rubber, and the remainder, that is the greater part of 60%, of such materials as the manufacturer thinks best. These materials are usually mineral matter, whiting, soapstone, talc or similar silicate, and metallic oxides such as those of lead and zinc. This type of compound has a temperature variation approximating that of the Hooper core; it was from one make of this type of compound that equation (*a*) was derived. There is another type of 40% compound in which the bulk of the 60% is made up of so-called rubber substitutes, which are organic substances, chiefly vulcanizing oils. This type of compound leaves very little ash when burned, showing that there is very little mineral matter in it, but the most remarkable property of it is that its temperature coefficient is approximately two for a difference of temperature of 12° F. assuming the simple logarithmic law, and is more accurately given by equation (*b*). The capacity of this compound does not appear to be increased so much by the highest voltage test as that as the other compounds.

All South American rubber of good quality is called in the trade Para rubber, and as the best of it is apt to come from the regions about the waters of the upper Amazon, the best quality of rubber is called up-river Para. This rubber makes the best insulation when it is a year old before it is manufactured. The Signal Corps specifications are always for 40% of Para rubber in the compound, no African rubber or reclaimed rubber of any kind being allowed. The natives in gathering the South American rubber start with a ball of clay as a nucleus; this they coat with the sap of the rubber trees and dry it over a smoky fire. Coat after coat of sap is applied until a "biscuit" as large as can be conveniently handled is formed. These biscuits, when they arrive in this country, are of a dark color, sometimes nearly black on the outside, but when cut open are found to be of a dirty white color on the inside, and the layers separate from each other more or less readily. This

rubber has a smoky smell, very much like smoked hams or bacon, but no offensive or putrid odor. African rubber, on the other hand, comes in small biscuits or nodules, is of a dark color clear through and has an extremely offensive, putrid odor, but no smoky smell. It is thus easy to tell one kind of rubber from the other before they are manufactured, but afterward they cannot be distinguished by inspection or by chemical analysis. African rubber is used to mix with Para in some of the cheaper insulated wires, but I do not know that any manufacturer uses it alone.

The tests of armor wire are chiefly mechanical; namely, tensile strength, elongation, twists in a given length, bending tests, etc. There is also a chemical test for the galvanizing. It is the practice of some users of cable in this country to armor with very large wire. The object of this is to protect the core from injury, after the manner of the shore end of a deep sea cable. Shore ends are usually made by putting an extra layer of armor over the outside of a deep sea cable, in which case there is no especial difficulty in using wire as large as is desired. When, however, heavy armor wire is used in the first layer there is sometimes considerable difficulty in laying it on over the delicate core without damaging it. For this reason the armor wire for cables of this kind is made of the softest iron procurable in the market, known in the trade as E. B. B. iron. These letters originally signified extra best bloom; that is the best quality of charcoal bloom iron, but as the iron is now made by the open-hearth basic process the letters do not mean anything in themselves, but are simply an arbitrary designation for the purest grade of iron that can be made by that process. There is no advantage, so far as I know, other than this constructional one, in using soft iron wire for armor. On the other hand, there is a great advantage in using a high tensile steel wire in deep sea work where great strength is one of the first requisites. Moreover, in the open-hearth process, steel is obtained before iron and when iron is wanted it has to be worked longer; consequently moderately high-grade steel wire is actually cheaper than iron wire.

In view of all these facts the Signal Corps has adopted 100,000 pounds per square inch as the standard for the ultimate tensile strength of armor wire, which is obtained without difficulty in a wire which is at the same time soft and flexible. The specifications for No. 10 B. & S. G. wire are: tensile strength

814 pounds, elongation in a ten-inch sample 10%, twists in six inches, 15. The actual tests show tensile strengths from the specified amount up to 1000 pounds and even more in some cases, elongations all the way up to 15% and twists as many as 23. The manner in which the wire breaks also shows it to be soft. When a hard wire is placed in the testing machine and tension gradually applied, scale reading increases to a maximum, then the wire suddenly breaks with very little decrease in cross-section or necking-in at the point of rupture. When the wire is soft, the tension increases to a maximum, then the wire cripples and the scale beam drops; no further pulling will lift the beam again, but the wire goes on stretching for one or two per cent. more, and then breaks at a considerably lower tension than the maximum. There is a great deal of necking-in at the point of fracture and the broken pieces resemble positive carbon butts from an arc lamp with a crater in the center. There is also a specification that the wire shall stand wrapping around its own diameter, but this is practically a sine qua non in wire that fills the other specifications.

The test for galvanizing is the one that has been used for a long time, both in this country and in Europe. Samples of the wire are immersed in a saturated solution of sulphate of copper and left for one minute; they are then removed, rinsed in clean water and wiped dry. This operation is performed four times, after which the wire should show no signs of a copper deposit. If the zinc coating be corroded through at any point, there will be a bright, firmly adherent deposit of copper on the exposed iron. This deposit will burnish on rubbing like good copper plating. Any copper deposited on the zinc is normally in a loose muddy condition, and is easily removed by the rinsing and wiping. Occasionally, however, there is a bright deposit on the zinc, but it can always be distinguished from the deposit on the iron by careful examination. Wire that has successfully passed the test is either the original bright zinc-color or a dark lead-color inclining to black, easily distinguished from copper-color. Another indication of the quality of the galvanizing is its behavior during the twist test. Poor galvanizing will all peel off, so that the wire before it breaks is bare iron (or steel), while good galvanizing is so closely united to the wire that after rupture the pieces are still covered with zinc.

American manufacturers are to be congratulated upon the manner in which they have met the difficult requirements of the Signal Corps specifications.

A paper presented at the 166th Meeting of the American Institute of Electrical Engineers, at New York, May 28th, 1902.

ELECTRICITY IN THE NAVY.

BY WALTER M. MC FARLAND

In discussing the applications of electricity in the navy my remarks as to specific installations will be mainly with respect to power plants and motor installations on shore, both on account of the fact that the company with which I am identified has done virtually no ship work for the navy, and because my own duties while a naval officer had little connection with such work. My experience, however, has suggested some points in connection with the use of electric apparatus on war vessels which may be of interest and possibly may afford some information.

The use of electricity in the navy was at first for purposes connected with the torpedo service, and when electric lighting became practicable its exploitation for the navy was taken up by the officers who had been devoting their attention largely to torpedoes. After some preliminary installations had been made, a board of officers investigated the conditions for lighting on war vessels with considerable care and formulated certain rules with respect to voltage, temperature limits, etc. Until very recently the general rules formulated by that board governed all installations on our naval vessels.

The standard voltage was put at 80, and in discussing the reason for the choice of this figure some time ago the Naval Inspector of Electric Lighting informed me that it was virtually determined by the requirements of the searchlights. It had been found that it was impracticable to use two of them in series, and as they required only 50 volts each, it

was felt that a higher voltage than 80 for the standard would cause too much loss due to resistance of the searchlight circuit.

The limits for temperature rise were considerably lower than had been found entirely practicable for standard practice on shore, and the explanation for using these lower limits was that the temperature conditions on board ship were much more arduous than on shore owing to the location of the dynamo room below the protective deck, which involved a very much higher initial temperature than that usually found on shore. Not to go into other details, it may be said at once that these requirements of low voltage and very low temperature limits, made the generators for naval use entirely special, with the result that unless some one concern could secure practically all the work and thus build enough of these machines to cover the development changes, naval work from a commercial standpoint would not be at all desirable. This explains why the company with which I am connected has made no effort to secure any ship work in the navy. Another large company, however, went systematically into the business of preparing to meet the demands, and as a result has installed the great bulk of electric machinery on our naval vessels. In view of the foregoing facts, it was somewhat surprising to read in the annual report of the officer having charge of electric matters in the navy a few years ago, the statement that he was in the hands of a monopoly, and that he advocated building electric machinery in the navy yards. As I told him when I once spoke to him about the matter, if the navy were satisfied to accept what everybody else found efficient and thoroughly satisfactory, there would be no trouble with respect to competition. As a matter of fact, government inspection is rigid and exacting to a degree which is not dreamed of in ordinary transactions, with the result that a machine, admirable in all respects but one, might be rejected on account of a slight excess in temperature rise in some one part. If the machines were standard in every way this would not make such a great difference, as such a trifling variation would not carry any weight with the ordinary customer; but when the machines are of such an odd voltage there is, of course, no way of selling them as they stand to any other customer, and consequently if rejected by the Government they would have only a scrap value.

In the report of the Bureau of Equipment of October, 1900, it was recommended that the navy standard of voltage be

raised from 80 to 110 volts, and that special dynamos of 55 volts be employed for running searchlights. The recommendation states that one of the advantages will be to increase the field of competition, and that facilities for obtaining supplies will be improved on account of the commercial voltage being 110. This, of course, is true, but it is only carrying the change half way. What should be done is to adopt the commercial standards throughout, which would enable the apparatus installed to be of the type that is steadily manufactured in large quantities at very moderate cost and for which repair parts could readily be obtained from the storehouses of the various companies located at the principal ports.

If the claims that the dynamo-rooms of war vessels are so abnormally hot as to represent conditions very much harder than any to which dynamos on shore are subjected were accurate, there would, of course, be ample justification for the low limits of temperature rise, but,as a matter of fact, there are places on shore where the temperature conditions of the dynamo-room are worse than on naval vessels. I have in mind a case where there was some delay in testing an installation in which I was interested, and the reason given for the delay was that the engineers who were to make the test were unwilling to stay in the dynamo-room long enough during the summer season to make the test, and insisted on waiting until cold weather had set in. Anyone familiar with conditions obtaining on shore can undoubtedly cite cases in his own experience where the temperature of the dynamo-room would run up to 140° or 150° at times, which is a higher temperature than I have ever heard cited for the dynamo-rooms of naval vessels. In all these cases standard machines with the usual limits for temperature rise have given satisfaction.

There is another very decided objection to the use of non-standard apparatus due to the low limits specified for temperature rise, namely, that the machinery must inevitably be considerably heavier. This is a point which appeals to me very strongly, on account of the fact that the main machinery in naval vessels is rigidly limited in weight, and the unfortunate contractor is compelled to pay a penalty for all overweight. It always seemed to me absurd that when such vitally important things as the propelling engines for driving the ship had a weight limit put upon them, the electric equipment was either not limited or, on account of peculiarities in the requirements

was allowed to be much heavier than it might have been if made according to the best standard practice.

As you are all aware, the use of electricity on board ship for power has been of comparatively recent introduction, the first important case being the turret-turning machinery of the *Brooklyn*, which was installed about 1896. This was followed by the more elaborate installations on the *Kearsarge* and *Kentucky*, where all the turrets were turned electrically and motors were also used for ammunition hoists, boat winches, ventilating blowers, and some other purposes. While I have not personally served on board of ships with electric power apparatus I understand that it has generally given satisfaction.

Among the chief reasons which appeal to the layman as well as the engineer for the use of motors rather than steam engines is the absence of long lines of piping, which unduly heat the spaces through which they pass in hot weather, and the avoidance of the chance of leakage. It would seem that on this line of thought, the two places of all others where motors should have been installed were for the capstan and steering engines, but while there have been a few officers in the navy to advocate this, the consensus of opinion has been against it. I do not know the exact reasons assigned further than a sort of dread that the motors would be unreliable, but I presume that where the objection was made by officers familiar with electric apparatus, it was due to the fear that in both of these places there would be times when the motor would be brought up standing under load, and under such circumstances direct current motors, unless protected by external safety devices, would be burned out, and these external devices would add to the complication and chance of derangement. It is undoubtedly a fact that both the capstan and the rudder are at times subjected to conditions where the motive power would be brought up standing, so that unless safe-guards were provided there certainly would be danger of serious damage.

This last point leads me to bring up the question of the adaptability of alternating current apparatus to use on shipboard. Indeed, I may say that although I had thought about it a great deal myself, the question was asked me by a naval officer during a recent visit to one of our large battleships, why alternating current was not used. Of course the immediate answer is that the naval authorities in charge of electric apparatus

still limit all electric machinery on shipboard to that operated by direct current. It seems to me, however, that the conditions on shipboard are such as to make the points which constitute the advantages of alternating over direct current apparatus of unusual weight. From the very nature of things the electric apparatus is to a considerable extent handled by men without a great deal of skill, a point to which attention has been called by the chief of the Bureau of Equipment in some of his annual reports, where he laments that the supply of trained men is not sufficient. Further than this, the induction motor, with its extreme simplicity and ability to withstand abuse and neglect, seems much better adapted to the general conditions on board ship than the more delicate direct current motor. With its ability to stand a tremendous overload and even temporary stoppage, it would answer for driving capstans and steering gear, from which the direct current motors have thus far been barred out. It would also seem admirably adapted for such work as driving the forced draught blowers for the fire-rooms, which are usually located in almost inaccessible places and where the steam engines now used to drive them, can rarely receive adequate attention when the blowers are driven at full power. Only recently I heard one of the ablest engineers in the navy comment on this very point, of the adaptability of the induction motor for this particular service. The only objection to the use of alternating current that occurs to me is the requirements in searchlights, but, as I remarked above, it is already proposed to install a special generating set, even where direct current is used, to supply the searchlights, and it will be perfectly practicable to put in a motor generating set giving direct current for searchlights, while alternating current would be used elsewhere.

While speaking about this use of motors in the department of the propelling machinery of the vessel, it seems pertinent to call attention to the fact that claims have been made for the adaptability of motors to drive the propelling machinery which seem ill-advised. These claims are based largely on the admitted high steam consumption of many of the steam auxiliaries against which a much lower steam consumption could be figured where these same auxiliaries were driven by motors. The fact must not be overlooked that on war vessels, as at present designed, the dynamo-room is at a considerable distance from the boilers, involving long lines of steam and exhaust piping, while the

steam auxiliaries in engine and fire-rooms are so situated that the steam and exhaust connections to them are very short. Further than this, while the steam consumption of these auxiliaries, considered alone, is undoubtedly very high, the fact was overlooked by those advocating the use of motors, and who were not familiar with the details of propelling machinery, that provision has for some years been made for turning the exhaust from these auxiliaries either into the receivers of the main engine, or into the feed water heater. In either case the steam expenditure was enormously reduced and the heat in the steam utilized to the fullest extent possible, under which circumstances their steam consumption per horse-power would be lower than that with the motor drive. It is sufficient to note that where the steam is turned into the receiver, the cylinders of the auxiliary become in effect an extension of one of the cylinders of the main engine and, consequently, the steam consumption becomes the same as that of the main engine, which even at reduced power is considerably below that of the small engines driving the dynamos.

There are enough places on board ship where motors may be used with great advantage, convenience and economy to make it unnecessary to urge their installation in places where they could not hope to give the satisfaction that is given by the steam auxiliaries, with respect to speed regulation, economy and weight.

My attention was recently called by a prominent officer of the navy department to a proposition made for sub-dividing the dynamo-room and having two, located in different parts of the ship, with the object of preventing the complete disablement of such vitally important parts as the turrets and ammunition hoists, in the event of a shell getting into the one dynamo-room as now arranged. I was very much surprised to learn that objection had been made to this on the score of complication, and I cited the case of the Explotadora system in Mexico, where there are seven a. c. generating stations scattered along the mountain side at distances of from ten to twenty miles from the receiving station, where the current from the different stations is brought together on the same bus-bars and transmitted to the city of Mexico. It seems to me that this proposition is an eminently sound one, and while there would, of course, be a slight increase of complication, it would be as nothing compared with the increased safety against total disablement.

Installations on Shore.—Naval requirements for electric machinery on shore are practically for standard apparatus, so that here the criticisms which I have made do not apply. Each bureau decides on the apparatus which it deems best for its own purposes, and all who make apparatus of the class wanted have an opportunity to bid. This brings up the natural inquiry from those not familiar with naval matters as to why there should not be a central plant for each navy yard, supplying all the current needed for use in the yard, whether for lighting or power. The reason why this has not obtained is, primarily, that all of our large navy yards have been established for some time, and they were at first entirely steam-driven plants. As the yards are of large area, with the different shops scattered, it was, of course, the best practice at the time they were laid out to have individual power plants for each set of shops. Under the existing system of appropriations some bureaus were able to install an electric drive earlier than others, and in this way we have the present condition, where in a single navy yard there may be several power plants, each for its own particular set of shops. I think there is little doubt that in any new yards that are established the tools will be entirely motor-driven and the current will be derived from one or more power plants. I say one or more, because it would depend on the location of the yard. Where a yard is isolated, as is the case at Mare Island, near San Francisco, or at the proposed station in the Philippines, it would seem unsafe to put the whole power plant in one locality, for the reason that any damage such as that caused by a fire, earthquake, or other disaster, would lay up the whole yard. Where a navy yard is near a large city or any establishment having a large power plant, arrangements could probably be made, in case of damage to the yard's power plant, to rent current for a time.

Most of the apparatus installed in the navy yards is of the direct current type, probably because the earlier installations were made before the induction motor had become so prominent as it has in recent years, and consequently as installations were increased the direct current was necessarily adhered to. In some recent plants, however, while direct current is used, the installation has been on the three-wire system from a single generator on the Dobrowolski system. This has enabled larger and fewer units to be used, with resulting satisfaction.

In two very interesting plants alternating current has been used, with induction motors of course, the first at the ordnance proving grounds and powder factory, at Indian Head, Md., and the other at the steam engineering plant at the Brooklyn Navy Yard.

At Indian Head the induction motors commended themselves on account of their simplicity and absolute immunity from sparking, but as it was desired to have a short line of railway with an electric locomotive for hauling guns from the dock to the proving range, and for other purposes, some direct current was also necessary and the generators installed are of the A. C., D. C. type. The railway is operated on what is known as the "button system," or electro-magnetic traction system. It was undesirable to have overhead wires, and an underground trolley would also have been objectionable, while the button system answers the requirements of the case admirably. This plant has been installed about three years and has given great satisfaction.

The plant at the Brooklyn Navy Yard has been only recently put in operation, although the contract for it was made in 1899, the delay being due to the fact that the power house was not completed until last fall. In this case the Bureau of Steam Engineering detailed an officer who visited important manufacturing establishments all over the country to ascertain the general opinion as to the best type of apparatus to install. He also visited various electrical manufacturing concerns to discuss with their engineers the merits of the different systems. As a result of his report, it was decided to use alternating current generators with induction motors for the tools, and the plant is an excellent illustration of the most advanced practice in the powering of a modern engine-building plant. Just about the time when this contract was placed, the large ship and engine-building establishment at Camden, N. J., known as the New York Shipbuilding Company, was also considering the question of electric driving, and after going into the matter very carefully under the guidance of a prominent electrical engineer, it also decided for alternating current with induction motors. In this plant there is an unusually large number of cranes, and as the crane builders generally charge a considerably higher price for alternating current cranes, it was decided to drive these by direct current. As a result, the two 500 k.w. generators are of the A. C., D. C. type, like the much smaller ones at Indian Head.

A comparatively new field for the application of electricity in the navy yard is in the dry-dock machinery, and in all the contracts made since the early part of 1899, it has been arranged that the pumps are to be driven by motors and that the capstans and winches around the docks are also to be electrically driven. Power drive for the latter would be practically impossible except by the use of electricity. Thus far all of these installations have been by direct current, but I believe there is little doubt that as the naval authorities who have charge of these matters become more familiar with the advantages of alternating current apparatus, this form will be used, because it seems much better adapted to the circumstances of the case than direct current.

Naval work on shore where electricity can be applied is largely in the nature of manufacturing and repair establishments, and consequently we would expect that the equipment which commercial manufacturers find to give them the best results would be adopted for the navy. This is, indeed, the case, and just as no large manufacturing establishment under private auspices now thinks of using anything but the electric drive for its tools, so the same thing is true of naval establishments.

With respect to the application of electricity on shipboard, the circumstances are such as to give a very promising field and my opinion is that if alternating current were adopted there would be a much greater number of motors installed than at present.

A paper presented at the 166th Meeting of the American Institute of Electrical Engineers, at New York, May 28th, 1902.

ELECTRICITY IN THE SIGNAL CORPS.

BY LIEUT. COL. SAMUEL REBER.

The application of electricity to the art of war has kept abreast with its development in the commercial world. The engineering conditions under which it is applied are practically the same as in ordinary life, but are prosecuted under conditions which, of necessity, must be more exacting and difficult. Efficiency and certainty of operation outweigh in the problem of design the cost of installation and economy of operation. Many ingenious means and methods of the application of electricity to the military service have been devised from time to time, but a large number proved of little value, as they have been either too complicated or too delicate. No device or apparatus which cannot survive lack of attention and skilled supervision, exposure to weather, rough handling in transportation, or the effect of the blast of heavy guns, will prove of value at the critical moment of its use at the time of actual battle.

Unfortunately for efficiency, the technical corps of an army is a very small proportion of its total strength, and the pay of the enlisted men is not sufficient to prove an inducement to men skilled in the use of electricity, who are much better paid for the same work in civil life, to enlist in our service. One of the greatest limitations of its development in the service has been lack of appreciation by Congress of its importance, and the consequent lack of necessary appropriations.

The signal corps of the army is charged with the construction, repair and operation of military telegraph lines, and the

duty of collecting and transmitting information for the army, by telegraph or otherwise.

While the importance and value of rapid means of communication in the commercial world have been demonstrated by the experience of over one-half a century, and the enormous amounts of capital invested in the telegraph, telephone, and cable, such means of communication are absolutely essential to success in modern war, where time is one of the most important of controlling factors. Electricity is the most potent agent in our control to effect such a saving of time.

The service of communication in the Signal Corps is divided into field and fortress work. For field work the telegraph, telephone and cable are now employed, and possibly in the future wireless telegraphy will be, when more positive results are obtained in working overland.

In the American armies, both of the north and the south, in the war of 1861 to 1865, was the first application of the telegraph under war conditions. The advantages and results proved so satisfactory, that nearly all of the foreign powers have followed our methods, and the present modern system of field communication is but an amplification of the results obtained in that war, taking advantage of the engineering progress and the recent developments in the arts of telegraphy, telephony and cable working.

A complete chain of communication must extend in an unbroken line from the extreme outposts in contact with the enemy, back to the capital at Washington. This chain of communication is divided into three parts: permanent, semi-permanent, and temporary, or flying lines. The permanent lines are usually those of the existing commercial telegraph and cable companies, and are, ordinarily, outside of the active zone of operations, and if taken possession of by the military forces, are operated under the methods of commercial practice. Semi-permanent lines are used to connect the principal base or depot of supplies on the edge of the zone of operations with the field base within it, and in this service the lines are constructed by using iron telegraph poles with cross-arms. Field or flying telegraph lines are used in the zone of active operations, and connect the field base with general headquarters and the general headquarters with all the principal sub-divisions of the army, even to the extreme outposts. A detailed description of the manner of erecting these lines will be given a little later.

For working the permanent and semi-permanent lines the ordinary closed circuit system of Morse, with the usual instruments, is employed. The invention of the telephone added a valuable adjunct, and especially so for flying lines, whose construction is at times most hasty, and whose insulation is so low that ordinary Morse working is often impossible. As troops advance it is frequently necessary to lay bare wire on the ground, hang it on trees, or even leave it in marshy ground, so that the circuit will be absolutely grounded for ordinary telegraph working. Under such conditions the buzzer has proved most successful, the delicacy of the telephone receiver making its use practicable. The buzzer is simply a coil of low resistance and high self-induction in series with a circuit breaker, a telegraph key and battery. On opening the circuit the discharge of the coil goes to line and, owing to the high self-induction and consequent comparatively high e. m. f., enough current reaches the telephone receiver at the other end of the line to give audible signals.

The telephones used in fortress service are modifications in design alone of the standard commercial types. Portability, simplicity, and mechanical strength are the essential features covering the design of all field telegraph and telephone apparatus, and will be illustrated in the description of the following special apparatus that has been designed bv various officers of the Signal Corps to cover field conditions.

While great progress has recently been made in the application of wireless telegraphy for the exchange of messages over water, its value for land communication, except in very exceptional cases, is quite problematical. The distances which as yet have been covered in land working, are of comparatively short length, and its certainty of operation without interference is as yet unproved. The existing methods of communication have proved sufficient, especially as a field line, under ordinary circumstances, may be erected at the rate of from one to three miles an hour, depending upon the character of the ground. Whenever absolute syntonic working is achieved and interference by the enemy can be prevented, wireless telegraphy may have a valuable field on land in the future, but at the present outlook, it is much more suited to the operations afloat than ashore.

Before the outbreak of the war with Spain the cable operations of the Signal Corps were confined to maintaining the

limited systems of cable communication between the various forts in the harbors of this country. When the expedition arrived off the coast of Cuba, near Santiago, the French cable leading to that point was cut, and, to avoid delicate questions of neutrality the first war cable ever laid by our government was run from Guantanamo to Siboney by the Signal Corps, and connected with the military line to Shafter's headquarters, so that the White House was only twenty minutes in time away from the firing line in an enemy's country.

As soon as the Philippine Islands were occupied, inter-island communication became so essential that the Signal Corps was called upon to take up the question of deep-sea cable engineering. Apart from its value as a means of communication, the establishment of the Philippine cable system gave the American manufacturers an opportunity to engage in the production of deep-sea cable, and has resulted in the establishment of such plants as will in future enable us to obtain at home this most important war material, and not place the government at the mercy of foreign producers, whose friendly interest cannot always be counted upon. It is interesting to note in this connection that the American manufacturers say they are prepared to make and lay the proposed American-Pacific cable, the project for whose construction is at present pending in Congress. The importance of the early consummation of this project, both for strategic and commercial reasons, gives rise to the hope that it will be settled at this session, whether laid under government supervision, or as a private enterprise.

The Type C apparatus, Figs. 1 and 2, is designed to use the buzzer principle, and is contained in a hardwood box of cubical form, 8½ inches on the edge, and weighs about eight pounds. The working parts are fastened to the front, which is hinged, and when in use lowered on a table. The back is also hinged to give access to the cells of dry battery that are contained in the body of the box. The transmitter and receiver fit in the space above the battery. A condenser of one-third microfarad capacity is placed under the board on which the working parts are mounted, and is connected to binding posts 2 and 3. The buzzer coils E are simply two coils wound in parallel, eight ohms each, one side of the windings of each coil being grounded on the frame at 8, and the other sides connected at 9. The circuit-breaker consists of a thin iron reed, fastened by a screw to the core of the left-hand coil, and supported in the

FIG. 1.

middle by a brass rod, which passes through a vertical standard at 12, and is capable of being adjusted by the two antagonistic lock nuts. There is a particular note for working, best adapted to each condition of the line, and this note is obtained by changing the tension of the reed and altering the air gap between the free end of the reed and the core of the right-hand coil. The two contact points at 10 are of platinum, and the pressure of the stationary contact point is regulated by an adjusting screw, which also assists in changing the pitch of the note given by the buzzer. The circuits are shown in Fig. 2. The receiver is at-

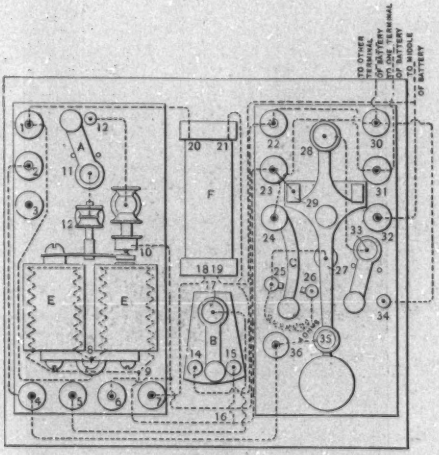


FIG. 2.

tached to 4 and 5, and the transmitter to 6 and 7. The switch A short-circuits the contact breaker; the switch B changes the connection from telegraph to telephone; switch C is used in changing from buzzer to ordinary Morse; switch D, when closed, puts one-half battery on the Morse circuit; coil F is an ordinary telephone induction coil. When in use for sending buzzer Morse A, is open, B is on 15, C on 25, and D open. For ordinary Morse A, is on 12, B on 15, C on 26, and D on 34. For telephoning, A is either open or closed, B on 14, C on 25 or 26, and D open. The battery, which consists of six dry cells, is connected with

30 and 31, the middle of battery with 32. The sending key is the ordinary telegraph key with an additional front contact 35, which is so adjusted that it will barely break when the key is up. When sending buzzer Morse the current passes through battery, key and coils to contact breaker and thence back to battery. Each time the current is broken by vibrations of the reed at the contact points 10, the coils discharge at 8 and 9, and go through 16, and as the key is down to 23 and 29, through key to 35 and 36 and 4 to 2 and line, 1 being earthed. In receiving buzzer Morse the current passes through 2 to 4, through telephone receiver to 5, and back through 15 and 17 and coils to earth. In sending ordinary Morse the current

FIG. 3.

is passing steadily from the battery to 30 and 34, through D to 33, to 28, through back contact of key to 29, and through coils as above, no buzz occurring as the vibrator is short-circuited. When the key is depressed the coils discharge, due to the break occurring at 28. This discharge goes to line as above, and gives a note in the receiver at the distant end. As the key is depressed, contact is made at 27, and current now passes from battery through 30 and 24, through C to 26, and through the resistance to 25 and 27, through the key to 29, and through the coils as above. The current is consequently weaker than before, and when the break occurs on the up-stroke the sound

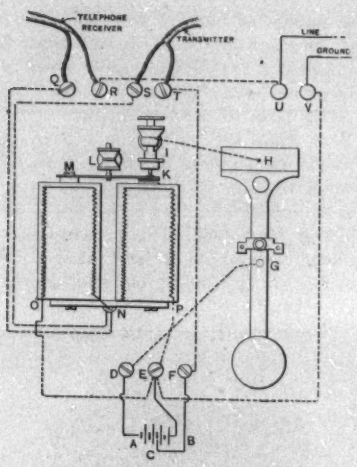

TELEPHONE RECEIVER
TRANSMITTER
LINE
GROUND
R
S
T
U
V
L
I
K
M
H
G
N
P
D
E
F
A
C
B

FIG. 4.

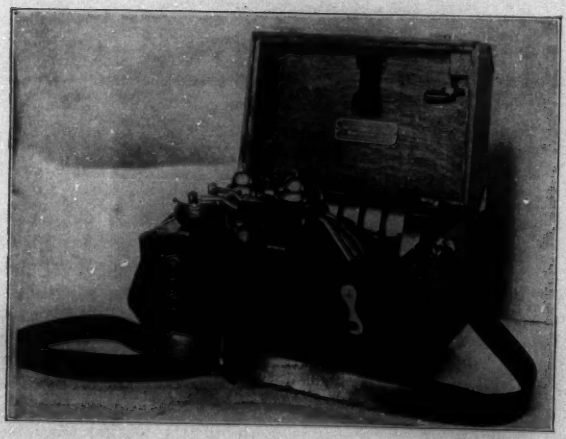


FIG. 5.

in the distant receiver is less than on the down-stroke; thus giving the same effect as with an ordinary sounder. The telephone circuits are the same as in an ordinary telephone. The condenser is used when it is desired to cut the kit in on a telegraph line, or for phonoplex work.

Type D, which is shown in Fig. 3, is a simplification of type C, and has proved invaluable in field service. It is enclosed in a leather case with straps, 6½x7½x4½ inches, and weighs about

FIG. 6.

seven pounds. It is used for buzzer work and telephoning, and the circuits are indicated in Fig. 4.

The field telephone kit, as shown in Fig. 5, is contained in a strong wooden box 11x7x7 inches, weighing 12 pounds. This kit is supplied with a magneto call, combined receiver and transmitter, and dry battery. The combined receiver and transmitter consists of a transmitter of the Ericson type, and watch-case receiver, which are connected by steel rods for strength; these steel rods form part of the

circuit, and are partially covered by a wooden handle, containing a compression switch for controlling the battery circuit of the transmitter. which is supplied by two dry cells.

The cut-in telephone, as shown in Fig. 6, is used for cutting in on ordinary telegraph lines to talk between repair parties without interrupting telegraphic communication, and for outpost service in the vicinity of a telegraph line. The wiring of the kit is shown in Fig. 7. It is contained in a strong, wooden box, $6\frac{3}{4}$x$5\frac{1}{2}$x$9\frac{1}{4}$ inches, weighing approximately eight pounds, and consists of a watch-case receiver R, of low resistance, a serrated metal plate P on the side of the box, a metal stylus S, coil C, which is wound to four ohms, the core consisting of soft iron wires projecting a couple of inches beyond the end, telephone transmitter T, battery switch B, four dry cells B–A, and

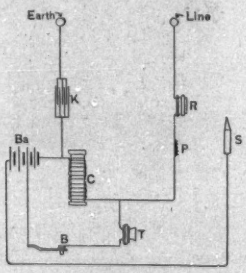


FIG. 7.

a one-microfarad condenser. When not in use the watch-case receiver, stylus and the mouth-piece of the transmitter are fastened on the inside of the door. When the stylus is scraped on the serrated plate the coil is charged, and discharges to line, giving a harsh rattling note, which serves as a call in the distant receiver, and when answered, the transmitter is used by closing the switch in the battery circuit. In case the two parties who are communicating with each other are on opposite sides of a telegraph station, the instrument at the station is bridged by a condenser.

The field telephone switchboard, as shown in Fig. 8, is for ten lines, and is contained in a stout box, 15x$9\frac{1}{2}$x$14\frac{1}{2}$ inches, and weighs 34 pounds. The line binding posts are on top of the box and protected by a hinged cover. The front and back are both

hinged for easy access to the working parts, which are mounted on a hard-rubber panel, countersunk in the front board, the bottom of which is recessed to hold the combined receiver and transmitter. The wiring of the board is shown in Fig. 9. The drops are of the high-resistance tubular type, permanently bridged across the line. The first row of keys are ringing keys, and the next three rows are cross-connecting keys, while the three keys below the panel are listening keys, each being connected to a line of cross-connecting keys. Turning down any two cross-connecting keys in any row connects these two lines. The listening key is bridged across the connecting strips in each

FIG. 8.

row. The board is supplied with a magneto-generator, and all the drops have the usual night bell attachment. Four dry cells are used, two each in series multiple. A strip of wood, faced with felt, is fastened to the rear face of the front door, in such a position as to keep the shutters of the drops from moving while the switchboard is being transported. This switchboard is very strongly and compactly made, so as to stand rough usage in the field without damage.

For small central stations, up to about 40 lines, a compact type of switchboard is shown in Fig. 10. The 20-line board is 25x9½x12 inches, and the 40-line is 25x9½x20½ inches. All

the working parts, except the magneto, which is fastened to the back of the board, are mounted on a hard-rubber panel inserted in the front of the board, which is hinged to the back-board, at the bottom of which, protected by a hinged cover, are the line terminals. The whole board is designed so that all parts will be easy of access, and its wiring is that of the usual practice, the operator's set being a combined receiver and transmitter.

The field searchlight section consists of a generator truck, Fig. 11, and a projector truck, Fig. 12. The boiler is the Cap

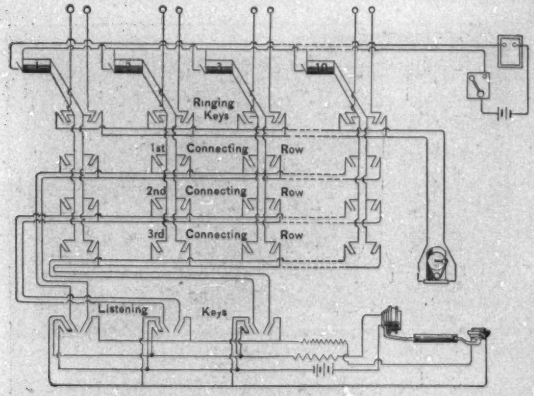


FIG. 9.

coil water-tube boiler, and steams equally well with coal or wood. The engine is a 3″x3″ direct-connected to a G. E. M. P. 6–2.5–800, 80-volt generator. In the photograph these are shown encased in Russia iron to protect them from the weather, and are situated just behind the water tank in front, the capacity of which is sufficient for a two-hours' run. Above the generator is a cylindrical oil tank. On the shelf between the boiler and engine is located the field rheostat, which is enclosed in a weather-proof covering, and a space is left on the shelf for a voltmeter and ammeter when the generator is in service. This truck can be easily hauled by two horses, and weighs, with fuel and water for a two hours' run, 5,300 pounds. The projector, which is the 18-inch type of the General Electric Company,

with both hand and automatic control, is mounted on the rear platform of the projector truck, which weighs 3,000 pounds. Spring-supported in the center of the truck is a box to carry the door and reflector, while the locker under the seat has compartments for 125 carbons, the voltmeter and ammeter and tools. Underneath the platform of the truck is the cable reel, which is fitted with contact rings, which are protected from the weather by brass housing. The cable itself is in one length of 1000 feet, twin conductor, 0.77 ohms resistance, this resistance being sufficient to give the proper drop from the generator to the arc. The projector can be trained 360° in azimuth, and from 30°

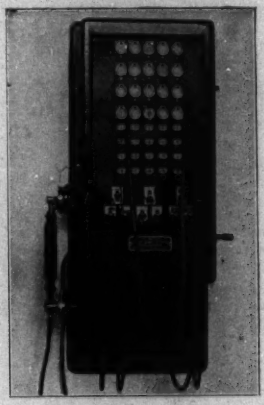


FIG. 10.

below to 70° above the horizontal. The projector is furnished with a radial shutter for signaling purposes, which slips as a hood over the door. This shutter consists of 16 over-lapping radial leaves, each one pivoted at its inner end in the central hub, and at the outer end in the frame. The inner ends are so connected in the hub that by partially revolving it by a lever from the side, the edges of the shutter are turned in the direction of the beam. The hub is spring-controlled, and the tension of the spring keeps the leaves of the shutter normally closed. By opening and closing the shutter, short and long flashes of lgiht, corresponding to the dots and dashes of the Morse code, bnacx e sent and signals echanged at night for long distances.

Messages can be frequently exchanged from distant stations, which are not intervisible, by throwing the beam on the clouds.

The material for constructing and operating the flying telegraph line is carried in the field telegraph train, which consists

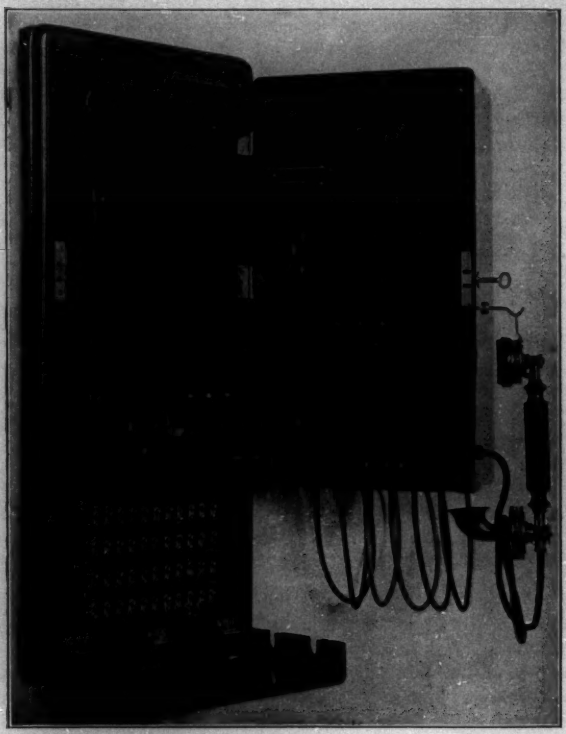


FIG. 10 A.

of three telegraph sections and a field searchlight section, which has been described above. Each telegraph section contains material for the erection of from 15 to 17 miles of line, and consists of a wire wagon and a lance truck. The lance truck contains 500 lances, 20 lance butts, hard-rubber insulators, and

the necessary digging bars and tools. The wire wagon contains 20 miles of wire, both bare and insulated, reels, line construction tools etc., several sets of instruments and stationery necessary for operating an office. Attached to the telegraph train is the battery wagon, which is equipped with a sufficient number of cells of the Eagle, Edison-LeLand, or storage type, to operate the lines. Battery is used at one end of the field lines alone. This wagon also carries the various types of field apparatus, serving as a central office for the system that is erected by the train.

FIG. 11.

The lances are of well-seasoned cypress or spruce, 14 feet long, 2 inches at the butt, and 1½ inches at the top, the lower end being pointed. The lance is tipped with a malleable iron ferule with a screw socket for fastening the insulator, which is of hard-rubber or gutta-percha, moulded on a standard that screws into the ferule. The insulators are of two kinds: slot and "pig-tail." In the slot insulator, the top is channeled for a depth of one-half inch to allow the wire to slip through it, and is supplied with a pin to prevent the wire from rising out of the slot after being placed therein. In the "pig-tail" insulator, an additional iron piece in the shape of an S is moulded in the

top. This "pig-tail" is used to keep the tension on the line by tying the wire around it. In constructing the line approximately every third insulator is of the "pig-tail" type.

In constructing the field line, after a preliminary reconnaissance has been made, the location of the lances is fixed by pins marking their position, the distance between the lances being from 50 to 60 yards. A working party equipped with crowbars sinks the holes, from 2 to 2½ feet in depth, according to the nature of the soil, and following this working party is the lance truck, which distributes the lances along the ground. The wire is then paid out from the wire wagon, following the lance line.

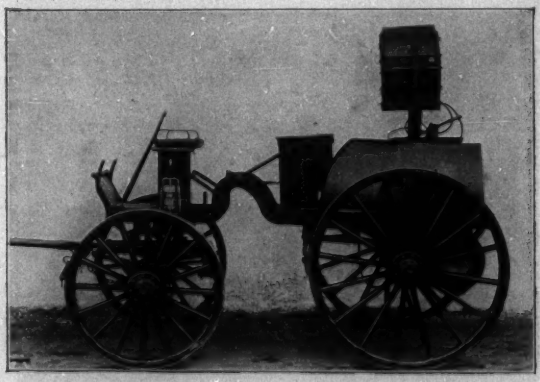


FIG. 13.

The wire is slipped into the slot insulators or tied to the "pig-tail" insulators, the lances then raised and inserted in the holes and tamped. When it is necessary to cross roads the lances are lengthened by a butt joint, which is of the same material as the lance, 10 feet long and 2½ inches in diameter, to which the lance is fastened by suitable clamps. In favorable ground a speed of three miles an hour has been obtained in erecting a line in actual service. As the advance continues the field telegraph train is followed by permanent construction parties, which erect either permanent or semi-permanent lines, depending upon the nature of the communication required. The maintenance of lines, especially when operating in an enemy's

country, is the most difficult, trying and dangerous operation connected with field communication.

For fortress service the most important system of communication is that for fire-control. Fire control is the system by which the officer known as fire-control commander directs the fire of the separate batteries under his command. The combination of two or more fire-control commands constitutes a fortress. The chain of communication is as follows: The fortress commander is connected with each fire-control command, each fire-control command with the position-finding stations of the batteries constituting it, and each battery position-finding station with the guns of the battery. The unit in fire-control is a battery, which contains from two to five guns, varying in type from the 12-inch to the small rapid-fire guns for the defense of the mine field. Each battery has a position-finding station, from which the range and azimuth of the targets are obtained. There are two general systems for determining this: the vertical and horizontal base systems. In the vertical base system the range and azimuth are obtained by direct observation with a range-finder, and in the horizontal base system by simultaneous observations from the two ends of the base line, the observed azimuths being communicated to a plotting room, where they are laid down on a specially prepared map, and the range and azimuth of the target determined. After this data has been obtained, by either system, it must be communicated from the battery command station to the guns, as well as certain tactical data as to the kind of shot or shell to be used, etc. As yet, neither our own, nor any of the foreign governments has reached a completely satisfactory solution of this problem. A number of devices have been tried: the telegraph is too slow, and requires skilled operators; the various systems of step-by-step printing telegraph are likewise too slow, and are easily thrown out of adjustment by the shock of firing: the telephone is unreliable as the transmitter is packed by the effect of the blast, and is uncertain, since in transmitting figures by speech, especially in the excitement of an engagement, mistakes are frequently made. The system that will successfully solve this problem must be simple in construction, mechanically strong so as not to be affected by the blast, as the receivers are placed close to the guns, rapid in operation, and give a character of record that can be read without liability of error. The communication from the station of the fortress commander to the

fire-control commanders is comparatively simple, as, owing to their location and the character of the messages which are exchanged, the telephone has proved satisfactory, but the line of communication from the fire-control commander to the guns is the one in which the difficulties have occurred.

A suitable system is urgently needed, and it is hoped that its development will be achieved by the engineering profession, as upon the successful working of the fire-control communication depends the efficiency of the defense of our sea-coast cities.

A paper presented at the 168th Meeting of the American Institute of Electrical Engineers, at New York, May 28th, 1902.

EMERGENCY ENGINEERING FOR HARBOR DEFENSE.

BY DR. LOUIS BELL.

During the recent difficulty with Spain I had the honor of being the executive and technical officer of the Volunteer Electrical Corps, which was formed in Boston to aid the United States Engineer Corps, and which was charged with the construction of the mining defenses and other emergency work in and about Boston harbor. This corps had, I believe, the distinction of being the first volunteer organization called into the service of the United States on the occasion of the Spanish War, being actually called out for active duty on April 4th, 1898, more than two weeks prior to the actual beginning of hostilities. It had its origin in the resolve of a small knot of electrical engineers headed by Mr. C. D. Haskins, who has dealt with one phase of the subject to-night, to give the best volunteer aid in their power to facilitate the arduous task set before Lieut. John S. Sewell in organizing the defenses of Boston. Lieut. Sewell was in actual command of the work during a large portion of the war, Col. Mansfield, who was officially in command of the station, having been detailed for court-martial duty, which lasted all the earlier portion of the time.

The preliminary organization was formed early in March, 1898, and before the end of the month had grown far beyond the original plan of its projectors. It was an organization in many respects unique. It drew from the strongest electrical organizations in and about Boston and from the ranks of the constructing and consulting engineers who were available for service. The original roster, which was placed on file at the War Department

when the plan received official sanction, numbered something over one hundred men, and about one hundred and fifty were engaged in the service at various times. The force consisted of three divisions, one charged with the preparation and loading of mines, another with the laying and maintenance of mines, and the third with the miscellaneous work of establishing communications and performing some of the heavier engineering work which fell to the lot of the corps. Each division was commanded by a division officer, and was again split up into several squads under the direction of squad officers, as responsible foremen. What was practically an adjutant's office was set up, through which the clerical work, purchasing and accounting of the corps was carried on, to be later reported in due form to the office of the U. S. Engineers.

Many of the important electrical organizations in Boston responded most promptly and patriotically to the call for men, telegraph and telephone companies, electrical manufacturers and contractors, joining hands not only in supplying workmen of the most reliable and competent character, but in permitting responsible and able electricians, high in their employ, to drop their regular work and take up their part in the organization of a national defense. It was fortunate that general business was slack during the war, for more than one concern would have found itself seriously crippled had there been anything like the usual pressure.

The corps was never mustered into service; in the first place, for the obvious reason that prior to the declaration of war there was no possible authority under which it could have been mustered in; and second, the body of men was such that they could not have been got together, unless in case of dire emergency, for working under purely military routine. Anticipating a sudden demand for work, an elaborate call system was arranged from headquarters to division and squad officers, and from them to the men, so that the entire body to the last man, I think, could have been gathered ready for orders in two hours from the time that their services were requested.

One fact worth mentioning for future records, in case a similar condition should again arise, is that all members of the organization were pledged to absolute secrecy regarding its operations, and, until it went into service, regarding even its existence, and it is a matter of some pride that its operations were actually kept from the public so long as any secrecy would have been of the slightest service from a military standpoint.

The corps was actually called out in part on April 4th and practically the entire work of the establishment of mine defenses, communications and range-finding stations in and about Boston harbor was done directly by it under the direction of Lieut. Sewell, the only extraneous assistance being given by a sergeant and four men, who ultimately were sent up from Willet's Point.

It is not my purpose here to review at length the work which was done. In brief it was as follows:

Two electric lighting plants for the forts were installed, together with search-lights and lighting systems for the casemates; three sections of submarine cable for telephonic and telegraphic communication were laid, connecting the forts with the mainland; a long semi-circle of telephonic communications was arranged, reaching from Nahant on the north to Hull on the south, in part composed of lines segregated from the system of the New England Telephone & Telegraph Co., and in part of aerial lines strung by the communications division of the corps.

Several hundred service mines were loaded, laid and maintained throughout the period of hostilities, following the scheme of defense outlined for the main channels by Lieut. Sewell. An equal number of temporary mines were prepared and made ready for service, for the extension of the mine defenses, by a pair of skirmish lines each nearly three miles in length. Firing stations and range-finding stations were constructed in connection with these skirmish lines and so arranged as to be serviceable for general range-finding purposes. In case of actual hostilities in the district, it would have fallen to the lot of the corps to fight, as well as to lay and maintain mine defenses, and the men were properly instructed in the handling of the mining casemates, which they had equipped.

The subject of the greatest interest at present in connection with this work is the matter of securing and utilizing of emergency material for mine defenses. A sufficient number of standard mines were available to equip in the main the principal channels. Many of the accessories were also put in stock, but the question of obtaining sufficient cable was a grave one. Some standard cable was secured through the U. S. Corps of Engineers, but much had to be bought in any place available and it was hard to find. One of the experts connected with the corps finally unearthed in a neighboring wire factory a couple of machines which could be used at a pinch for armoring, and a considerable

amount of cable was constructed to eke out the otherwise scant supply. For telephone cable nothing suitable for submarine use could be obtained from stock or prepared on short notice, and as a last resort a four-wire cable of good quality was lead-covered and laid, with some misgivings as to its durability. It gave excellent service through the period of the war and the first break-down, oddly enough, occurred on the day the protocol was signed. Wire cable for mooring the mines was obtained on the ground, and for supplementary anchors, where such were needed, a lot of old rails answered the purpose excellently. Gutta-percha wire for certain of the mine connections was troublesome to obtain and some special rubber-covered wire, made carefully to size, was tried in experimental fashion, and ultimately we secured a sufficient quantity of the standard wire. The question of explosives was easily solved. A sufficient amount of Kieselguhr dynamite, mostly in long sticks, was obtained for filling most of the standard fuse plugs, but for filling the mines it was necessary to fall back on commercial products and the bulk of them were loaded with No. 1 wood-pulp dynamite, carrying nearly 75% nitro-glycerine and packed rather loosely in 5-lb. paper cartridges. A considerable quantity of blasting gelatine in 5-lb. packages was also used, and on the whole with very good results.

For the emergency mines, after considerable deliberation, we relied on standard beer barrels of the usual size. These were extremely well-made casks, heavily iron-bound and with oak heads 2½ inches thick. For these mines fuse plugs closely resembling the service fuse plugs were made, the firing device being, however, slightly more sensitive. The fuse cans connected to these plugs were filled at the end away from the fuse and sealed with corks and red lead, which appeared to make a joint excellently water-tight, for at least a considerable time. The body of the plug was made to take a large hexagon nut and was cut with a slightly taper thread. The casks were bored by a 3¾-inch ship auger, rigged with long handles and supported by a temporary drill press, and the hole was then cut conical with a special tap made to match the threads on the plugs.

Armored cable could not be obtained in quantities sufficient for supplying the needs of the long skirmish lines of the temporary mines which had been prepared and we therefore fell back upon lead-covered wire. The Spanish fleet was located before the skirmish lines were laid down, so that only experimental

mines of this construction were put out, but our results showed that while the lead-covered wire was adequate for all ground cables the risers to the mines would have required constant attention on account of insufficient mechanical endurance of the lead-covering in case the mines swayed and turned for a considerable period in the tideway. For the grouping of the emergency mines, small cast-iron junction boxes were designed and made, which, after the joints were formed in them, were filled with Edison compound, such as is used in the underground service of the Edison Company. This construction appeared to give a tight and durable box, although not one well adapted to stand heavy mechanical strains.

Anticipating some leakage from the long lines of lead-covered cable, a firing plant was erected, consisting of a small 500-volt dynamo connected to a 5 h.p. oil engine, so that even in spite of severe leakage a firing current could still have been passed through the fuses. On account of the great length to be covered, the temporary mines for the skirmish lines were arranged to be fired in groups,separate cables leading back to the firing station from each group. As contact mines, connection was made between the fuse plugs of each group and a firing relay, which served to admit current to the group as a whole. To economize in material, individual mines were designed to carry a charge considerably in excess of the ordinary service charge and were spaced more widely than usual, the interstices being occupied by small kegs carrying contact-firing plugs, only without charge and arranged to admit current to the firing relay for the group.

The skirmish system was laid out in a pair of long, straight lines. Nearly opposite the middle of each line and far inshore was a signal station with a transit instrument in telephonic communication with the firing stations, which were supplied with observation telescopes, the alignment of the line of mines being established by the latter. The particular group over which an enemy might approach could be instantly designated from the bearing obtained from the signal stations, so that the proper group could be fired by observation without difficulty. Incidentally, the firing stations were at sufficient elevation to locate the groups by depression angles, if the communication had been interrupted. Experiments conducted with these temporary mines showed that they had sufficient explosive efficiency and could be spaced at substantially the distance of the standard mines without throwing each other out of action by the explosion.

The principal difficulty encountered in the mining work, was the maintenance of the standard mines in the channels frequented by shipping and where the tide ran rather swiftly. In spite of the most explicit orders and patrol kept up by revenue cutters, vessels sneaked up and down the channels under cover of night and caused almost constant trouble from fouling of cables. At certain points in the channel the mines were kept out of the way by being shackled down low on the anchors as ground mines, but where they were installed in the usual way, keeping them in order was a matter of incessant work and the division charged with this job found itself and a couple of lighters busy nearly all the time.

A considerable number of mines were struck by propellers of passing vessels and sometimes cut open and sunk. I have seen one of the larger service mines, carrying 150 pounds of explosives, cut open by a propeller blade from near the top to down within six inches of the charge. Only Providence, that looks out for fools when it ought not to, prevented at least one steamer from having her stern blown off. Every few days one or several crippled mines had to be taken up, brought back to Fort Independence, which was used as a base for the mining operations, and replaced by another mine. The damaged mines were taken out into the shallows off the channel and exploded, as the easiest way of getting rid of a somewhat dangerous neighbor.

It was found that the wood-pulp dynamite would not stand salt water well, the pulp being apparently unable to hold the nitro-glycerine with anything like the tenacity of the Kieselguhr dynamite. In one instance a striking and nearly calamitous evidence of this was furnished. A large mine had been brought up from the bottom with a damaged fuse plug. It was taken into Fort Independence and one or two men of the corps with a couple of engineer soldiers started to take out the dynamite to examine into the condition of affairs. The whole packages were removed easily enough. Some of those which had come open from exposure to the water were scooped out in the best manner possible, and finally all the dynamite was removed and the interior wiped out with waste. This was before we had had much experience with damaged dynamite, and becoming a bit suspicious of the condition of the mine, which was lying on the parade ground where loading was frequently going on, I directed the soldiers to take it outside the fort and fire a couple of primers into the interior to make sure that it was free from nitro-glycer-

ine. With some covert scoffing they carried out this instruction, and five minutes later I heard a tremendous detonation and as I jumped out through the sally-port I was met with a suffocating volume of smoke. The body of the case, weighing some 400 pounds had been thrown end-over-end a distance of perhaps 50 feet, and with the head complete, was found later in shallow water about 200 yards away from the point of explosion. The nitro-glycerine from the damaged dynamite had soaked into all the crevices of the case and formed a coating over its interior in sufficient quantity to produce this unpleasant result when a couple of service primers had been exploded in the interior.

It was usually found that the dynamite which had been wet was not in good explosive condition, and a detonating charge in a small keg was usually placed in or alongside a damaged mine to insure its complete destruction. On one occasion I obtained a fine example of an explosion of the second order in a large mine fired in this way. The detonating charge exploded with great violence, while the mine itself seemed to hang fire for a small fraction of a second, and then came an explosion of a second order throwing up a comparatively small volume of water to a very moderate height. One point with reference to these submarine explosions is worth noting. It was our uniform experience that while after the explosion of a 100 or 150-lb. charge a good many small fish were found floating on the surface killed, nearly all of the larger ones, in fact, perhaps the majority brought to the surface, recovered and swam away; a fact, which may possibly account for the absence of floating fish, alleged to have been noted shortly after the destruction of the *Maine*.

Damaged dynamite which had been removed from mines was sometimes exploded experimentally when merely repacked in the cases from whence it came. Under these circumstances it was sometimes remarkably insensitive, only exploding properly when a cartridge of dry dynamite was used as a primer. The blasting gelatine was subject in a measure to the same defect, and showed a slight tendency to leak nitro-glycerine if a cartridge were left on end, where it was exposed to the warmth of a summer day for some time. This slight instability appeared to be due to the character of the nitro-cellulose used in making it. It did not seem to be uniformly of the nitration required for the production of a first-class gelatine, and commercial gelatine should be employed for military purposes with great caution.

We arranged a little testing laboratory, where we regularly sampled and inspected the explosives delivered and tested them

from time to time to assure ourselves that all in the magazine were in good condition. The Kieselguhr dynamite is certainly much superior to the ordinary commercial product in stability and capacity for holding a large percentage of nitro-glycerine. I am convinced that the very grave accident costing the lives of several men, which occurred after the war, while a squad of engineer soldiers was unloading some of the mines which had been taken up, was due to the instability of the explosive producing a hypersensitive state, which resulted in detonating the contents of a mine by a very trivial fall.

From our experience with the service mines, which first and last was considerable, I find myself very unfavorably impressed with the contact device then in use and with the method of placing the floating mines. We found constant trouble in the tideway from the twisting off of the mooring cables. The mines in parts of the channels were in a perpetual state of slow revolution, making two or three turns in one direction and then two or three in the other within a period of half a minute or so, and with the result of damaging either the mooring cable or the firing cable in a very large number of cases. Some relief was obtained by allowing more slack, but were I again directing similar operations from a technical standpoint, I should certainly be inclined to employ heavily charged ground mines, used mainly or entirely for observation firing, to a very much larger extent than was the case in 1898. We tested both service plugs and the plugs for the temporary mines, which were decidedly more sensitive than the service plugs, on a number of occasions by running down a dummy mine with one of our tugs, and in most instances the mine was merely pushed aside without making contact. At high speed, or when hitting the mine very squarely, contact would doubtless be made, but were a ship proceeding with the caution necessary in a fog, when observation firing would be impracticable, I think her chance of going through an ordinary line of mines, as then arranged, without firing one by its contact mechanism, would have been very good. In fact, I very much doubt whether, with a mine as near the surface as it is likely to be when a considerable rise and fall of the tide has to be allowed for, it can be provided with a contact device certain to act when struck by a ship and be at the same time sufficiently insensitive to avoid frequent contacts from waves and tidal swinging. I am disposed to think that reduction of the contact feature of the mining system to a set of tentacles, controlling the firing of a deep shackled or ground mine with a very heavy

charge, would render it more useful in an emergency and vastly easier to keep in operative condition. I believe such an arrangement is used in the British service. Explosive is cheap and the fewer actual mines, the greater is the deadly radius of action of each of them, and the less likely is the fundamental cable system used for observation firing to become disarranged. With contact devices serving merely as tentacles, I think a careful operator in the casemate would soon become acquainted with their idiosyncrasies, so as to fire the mine manually in response to the action of the tentacles with far more certainty than could be secured by contact mines of the ordinary kind. Incidentally, ground mines, with the cables lying on the ooze at the bottom of the channel, are far more difficult to put out of action than mines lying nearer the surface, with a network of mooring cables which can be damaged or cut loose.

Our experience showed what will be of service in future emergencies, that starting with a force of trained electricians and workmen such as can be obtained in almost any large city, the intricacies of a mining system can be very quickly mastered by men having no previous experience with them and mining defenses very quickly and thoroughly organized. This was also the experience at several other points where efficient volunteer organizations were in service.

I presume that had the necessities of the case been more severe, interference with the mining defenses by straggling vessels could have been and would have been very much reduced, but it is a serious matter and one which should be averted, if necessary, by very drastic measures in time of war.

In point of fact, we had but one real alarm at Boston. Once, just after our force had got through its day's work and was scattering, a telegram came from the War Department announcing the appearance of a fleet of uncertain aspect off the coast. There was scurrying for a time and the firing squads were promptly assembled and sent to the casemates. For that night, at least, the mines were thoroughly ready for business, but in the morning our suspense was relieved by the announcement that we had been victims of a false alarm.

After about ninety days' service, the Spanish fleet having been snugly located at the bottom off Santiago, the Volunteer Electrical Corps passed out of existence, but the experience was a valuable one, in showing both the amount of material and men which could be gathered at short notice and in teaching some of the limitations involved in hurried and temporary construction.

Discussion.

President Steinmetz:—We have concluded the presentation of papers, and discussion is in order.

Colonel Reber:—I consider the first paper of the evening one of the most suggestive, and, speaking for one branch of the service, I am sure that the more coöperation we can have from the electrical engineers as a body or individually in solving the problems presented to the Army, the more it will be appreciated by us, not only collectively but individually, and by the War Department as well.

Lieut. George:—I cordially agree with what Col. Reber says. I have noticed in many instances the great advantages that arise by coöperation between the professional electrician in civil life and the naval officer, who is best able to appreciate the conditions existing on shipboard and the requirements of the service as far as the application of electricity to naval purposes is concerned.

With reference to Mr. McFarland's statement as to the desirability of double dynamo rooms on board ship, I would say that many years ago this system of installation was proposed and frequent references are to be found in the early discussions on naval installations. It was contemplated to install a peace dynamo room above the protective deck, in a well-ventilated compartment to supply the normal demands, and a war dynamo room below the protective deck for battle purposes. The improvements in ship's ventilation have rendered this distinction unnecessary. Electric power itself solved the problem by enabling any compartment to be efficiently ventilated. This is particularly the case in the *Kearsarge* and *Kentucky;* the electric ventilating systems of these vessels are most admirable, due to the efficiency of the electric drive and the arrangement of piping. There are several foreign men-of-war equipped with double dynamo rooms. A recent Italian ship has an arrangement very similar to the scheme proposed for the 16,000-ton battleships, except that no dynamo room is sufficiently empowered to supply the entire battle output. Each dynamo room is capable, however, of operating the load of lamps, and all auxiliaries at reduced speed.

I have recently seen an opinion expressed by an eminent officer of the French Navy, on this subject. He does not advocate dynamo rooms widely separated, but suggests that the rooms be entirely independent electrically, that each be capable of handling the battle load, but that they be situated close together, in a central position for economical distribution, and separated by a water-tight bulkhead, communication being made by signalling appliances.

The Navy specifications set the following as the allowable temperature rise after a 4-hour run at full rated load. Armature and field 33½°C., commutator 40°C., shunt rheostat 75° C., and series shunt 40°C. In the report of the Committee on standardization,

it is recommended that the following maximum values of temperature elevation should not be exceeded. Armature and field 50° C., commutator and collector rings and brushes, 55° C.

The high temperatures in the shore installations referred to by Mr. McFarland are the exception and not the rule, and the commercial practice as indicated by the report of the Standardization Committee contemplates the normal condition of installation rather than the few isolated cases that occur in which dynamos are installed in hot and poorly ventilated cellars.

It is not uncommon on board ship to find temperatures of a dynamo room recorded in the electrical log books at from 120° to 130° F., for periods of several hours duration, and in some cases the temperatures are in excess of these figures. If we take 125° F. as a temperature to which naval generators may be subjected for several hours and the maximum permissible temperature rise accords with the specifications, the armature and fields will reach 185° F. This, under the commercial practice, would be the temperature of the armature and fields of a machine running in a dynamo room at 95° F., which would represent a common average during the summer. I think it is safe to say that the temperatures of our dynamo rooms average 30° or 40° F., higher than those on shore.

Mr. McFarland cites the inexperience and lack of skill of the men entrusted with the care of electrical apparatus on board ship. The early installations were looked out for by the gunner's gang, good men in their way, but without experience in electrical work. The electrical force now consists of men specially selected for this purpose, rated as chief electrician and electricians of the first, second and third classes, with a scale of pay more commensurate with their duties, and the growing importance of electricity on shipboard. I have frequently heard references to lack of care displayed in the operation and maintenance of ships' plants and I am of the opinion that it is more assumed than real. The best answer to the question is that the electrical portion of our personnel does operate and maintain expensive and elaborate light and power installations for years at a time, far removed from sources of supply and facilities for repair, and under conditions much more exacting than those obtaining on shore.

As regards the direct current motor, it performs its duty whenever installed, and I can see no reason why it could not be installed whenever the electric drive appears desirable. On the *Kearsarge*, the boat cranes were operated by direct current motors, mounted on turntables on the rails, exposed to the weather, and frequently flooded by seas breaking over the rail. During my term of service in this ship, some eighteen months, these motors were in constant use day and night and I do not remember a single instance of breakdown. The same remark applies to the electric deck winches, which were always ready for action. So successful have these motors been, that the steam drive orig-

inally prepared on the ships under construction for manipulating boat cranes, have recently been changed to electric power. I consider the direct current motor eminently adapted to the forced draft system, the inaccessibility of the location being in my mind a prime factor for preferring it to the reciprocating engine.

GENERAL EUGENE GRIFFIN:—I have listened with very great interest to the reading of the papers of the evening. I think they been very instructive to us all.

The method followed in our country has been to have a comparatively small standing army, and to rely upon volunteer troops in time of war. Thank God, we have a larger army now than we had ten years ago, but it is still small in comparison with the necessities in time of war, and we must always call upon the volunteer troops to build up our army. We must in the same way, of course, call upon our volunteer scientists in times of war, however well equipped we may be with those who have studied at the national academies. It goes without saying that when the emergency arises there will not be enough trained men. We must have a force which is able to execute the work under the direction of the proper officers, and that force must be taken from the men who up to that time have been doing their work in civil life. Mr. Haskins' work has been spoken of, and I happen to know something of his experience in Boston, and I wish to endorse cordially what has been said by Col. Reber and Capt. Sewell as to the services that Mr. Haskins rendered there.

When the emergency comes we must also call upon the manufacturers. I happen to have been in the Corps of Engineers, and I know something of the conditions of the Corps. In talking with some of the engineer officers in Washington about the time of the breaking out of the Spanish-American War, I asked them what they were going to do about searchlights at the fortifications. I remarked that when I resigned we had only one searchlight for the entire fortifications of the United States. They said as soon as they had some money they were going to buy some. Forseeing what the conditions were, and realizing the necessity of getting large lenses, I cabled to some of our people abroad and directed them to buy every 24, 26 and 36-inch lens in the market. Within one month they bought eight lenses, and a week afterwards seven more, and they could buy no more. That is simply an indication of the difficulty of getting very quickly that kind of material which is necessary in times of war. I want to add simply that I hope the result of this meeting will be to bring about some cōoperation between the officers of the Army and Navy, and the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, which will lead to the possible organization of some kind of volunteer electrical corps, and which will lead to that closeness of relations which I am sure will be of very great value to the country in case of any further hostilities with foreign nations.

MR. ARTHUR V. ABBOTT:—There is one paper this evening

that puts me somewhat in the position of Oliver Twist; that is, I wish there was more of it. I refer to Lieut. Beecher's paper upon the transmission of intelligence without wires. It is a subject in which I was very much interested some time ago when I had more time to bestow upon that portion of the electrical field which is experimental; so the chief thing I have to offer in the way of discussion this evening is some questions. Could Lieut. Beecher tell us anything as to the amount of power required to transmit signals over varying distances? Can we have any information as to the speed which signaling has attained? How many words a minute can be sent? How fast can transmission be, particularly with the newer forms of receiver? What is the best form of telephone for receiver; the high-wound or the low-wound receiver? Mention is made of increasing the height of the masts on vessels; is that done because greater distances can be attained by increasing the heights of the masts, and has any new formula been developed since the one enunciated by Marconi, that the distance varies as the square root of the height of the mast? The use of the anti-coherer is certainly novel. In that type of receiver is a telephone employed, and are the audible signals produced by a variation of current in it? Have any experiments been carried on as to the actual transmission of speech? I made some experiments in that line myself, and I succeeded in transmitting speech over short distances, but it was not successful when attempts were made over a mile or two. Possibly that was owing to the conditions which the paper mentions,—the difficulty of transmitting signals of any kind on land. We all know that very few successful experiments over long distances have been made in the transmission of signals of any kind over land. What kind of a microphone is the best? Is the carbon microphone the best? Why should not a telephone receiver be a good receiver? If my five minutes is not up, Mr. President, I would like to have the remainder of it used by some of the gentlemen in answering the questions that I have asked.

LIEUT. BEECHER:—I do not think I can answer all the questions that the gentleman has asked. Moreover, I have not jotted them down, and I will ask him to recall the questions to me and I will endeavor to answer them as far as I can.

MR. ABBOTT:—First, the amount of power?

LIEUT. BEECHER:—I cannot say off-hand the amount of power used, but I can say that very little power is required. I do not know how much Marconi used, in his recent long distance (Trans-Atlantic) experiments, but I do know that he was using very much more power than has been used heretofore.

MR. ABBOTT:—What about the length of sparking distance?

LIEUT. BEECHER:—With a coherer receiver, signaling 40 miles over water, about 1½-inch sparking gap is ordinarily employed, using Prof. Fessenden's receiver. I noticed some experiments where he was signaling about the same distance (45 miles) over

fresh water, which is harder to signal over than salt water, and where he was only using between ¼ and ½-inch spark gap.

MR. ABBOTT:—What about speed?

LIEUT. BEECHER:—The best speed, using a coherer receiver, is, I suppose, about twelve words a minute; but with a telephone receiver that can be increased very largely. With Prof. Fessenden's apparatus a few weeks ago, down in the North Carolina swamps, he was signaling with unpracticed operators about 25 words a minute. The speed with his apparatus was only limited by the ability of the operator to send and receive. You might say it was more rapid than any land instrument could be worked.

MR. ABBOTT:—What about the height of the masts?

LIEUT. BEECHER:—I think most people have changed their ideas about the height of the masts affecting the distance of transmission as the square root of the height. I think the distance varies more nearly as the height of the masts.

MR. ABBOTT:—I think Signor Marconi was the originator of the law that it varied with the square root of the height.

LIEUT. BEECHER:—I do not think I have seen that statement of his.

MR. ABBOTT:—I think you will find it in a paper of his published or read before the INSTITUITON OF ELECTRICAL ENGINEERS of England about two years ago.

LIEUT. BEECHER:—I cannot state definitely about that. From my own knowledge and experience, I do not know; but I have an idea that the distance of transmission varies more nearly as the height. I think perhaps Captain Russell or Col. Reber can answer that question better than I can.

MR. ABBOTT:—I also think Col. Reber could give us some information on this subject.

COL. REBER:—I can say that so far as my own experiments are concerned, I have not worked with sufficiently great distances to prove whether or not "the law of the square root" is correct. I have assumed in a general way that Marconi's statement is correct when the energy is the same at the different distances, and until I have more data I would not like either to affirm or deny the statement. We worked over certain distances and got certain results, but the great difficulty with the ordinary coherer is that its sensitiveness, not being the same on two different occasions, the height for the distance on one day would not be the same for the same distance on a subsequent day.

MR. ABBOTT:—That is exactly the same experience that I have had.

COL. REBER:—I think that with Fessenden's coherer he can work a much greater distance with less energy, because this type of receiving apparatus works on an entirely different principle from the coherer. He has shown his system to several officers both of the Army and Navy, but as yet has not published his methods, owing to the patent situation.

MR. ABBOTT:—Can you tell us something more about the anti-coherer?

LIEUT. BEECHER:—I just brought that out because it seems to me to be so radically different from the coherer. Take a mirror and scratch it so as to divide the silvering and connect the portions up in an ordinary cell circuit; the effect of the spark there is just the opposite from the effect with a loose contact, or with a coherer. In other words, the action of the spark materially increases the resistance of the circuit, instead of reducing the resistance, as it does with a loose contact.

MR. ABBOTT:—Do you think that offers any new form of transmitter?

LIEUT. BEECHER:—It has been utilized abroad, and it is utilized in the De Forest system in this country, which I do not think has been made public yet, but I understand he has gotten some very good results in speed, and claims quite good results on distances. It has also been used abroad in some of the German systems.

MR. ABBOTT:—I think Prof. Bose was the first one to call attention to the varying, so to speak, coherer action. Have you made any experiments in the transmission of speech?

LIEUT. BEECHER:—No, sir, I have not, but Prof. Fessenden claims, and I have no doubt his claims are very well substantiated, that with his system he has completely solved the question of the transmission of audible speech, and, as Col. Reber says, his system has not been given out to the public yet on account of the foreign patents. Without doubt his system is better adapted to that than any other I have knowledge of, and he claims that he can transmit audible speech.

MR. ABBOTT:—Are there any facts as to the kind of microphone?

LIEUT. BEECHER:—No, sir, I have not any. Of course, a great many different kinds have been experimented with. I witnessed a very interesting experiment conducted by Capt. Russell the other day. If he will tell us something about it I think it would be very interesting to you all. It brought very forcibly to my mind the using of a loose contact with a relay and Morse recorder. I did not know when I saw Capt. Russell's apparatus that this had been done before, but afterward in reading on the subject, I found that Prof. Branly had done the same thing. Of course the coherer, as we all know, is very unreliable. The more we reduce the number of filings, perhaps, the more reliable it is.

MR. ABBOTT:—In other words, the more you work it, the worse it is.

COL. REBER:—I will answer one of the questions about speed. In one of our installations, where seven or eight thousand words are sent daily, the average rate is about twelve words a minute, but would sometimes run to twenty-five or twenty-six words, using the ordinary coherer.

LIEUT. GEORGE:—I would like to ask for reliable data as to the

steam turbine. It would appear from the advertisements and tables of performance published by the manufacturers from time to time, that the water consumption of a steam turbine, coupled to a generator, per kilowatt hour, is much less than that of a reciprocating engine of the same capacity. Also that the variation in consumption is not so great as the difference in water consumption between large and small reciprocating engines, and in all cases the steam turbine appears more economical than the reciprocating engine. If any member of the INSTITUTE is in a position to give me the figures from actual tests and any information as to the performance of the various types of bearings in this connection, I would be much obliged to receive it at Washington. This would be in line with the coöperation referred to this evening

PRESIDENT STEINMETZ:—We have with us here to-night Gen. Greeley of the United States Signal Service, and I should be very pleased to have him address us.

GEN. A. W. GREELEY:—The Secretary was kind enough to ask me to write a paper for this occasion, but I was not able to do so; I have not been able to formulate any remarks for this evening, either. I have listened with great pleasure to the papers, and with profit. I would like to say that the spirit of coöperation between the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS and the Army and Navy branches of the military service of the United States is fully in accord with my own ideas and practice. I am very sorry for any chief of bureau who has of necessity to call in outside help for the men of his corps; but, on the other hand, I am very sorry for a chief of a bureau who does any very important work through the officers of his corps when he can get it done by the civilians of his country. It has been my belief that a man who does a thing well from early Monday morning until late Saturday night can do it better than any officer of the Army or Navy. I have, in the Signal Corps, officers who are capable of doing any class of electrical work, but I have never permitted them to do any piece of work which I could hire done by a civilian. The work on the south coast of Cuba, and in the interior of China, and in the Philippines, which has brought a certain credit to the Signal Corps of the Army, and I believe a still greater credit to the American nation, has been forced by war conditions upon the American soldier, and I believe the American soldier is, as the American himself, the best type of his kind. Many are fond of speaking of the difference between the regular army and the volunteer army. Gentlemen, there is no difference. They are all volunteers. The only thing is that the regular comes in for three years, while the volunteer comes in for three months, or nine months, or a year, as the case may be. They are men of the same education, of the same standing, and, whenever Congress in its wisdom puts limitations on them, applies what I have said is the proper doctrine for the Army, as it is for the evolution of American industry, the doctrine of selection, of competition, and of elimination—when these things are given to a corps, as

they were given to the Signal Corps at the beginning of the Spanish-American war, there always will be results satisfactory to our people. Because Congress did permit the Signal Corps of the United States, or the chief signal officer of the army, to enlist or commission in his corps, men of whom two-thirds must be electricians or telegraph operators, that moment it was a certainty that the work done by the corps would be successful. I have always followed those lines, and I believe that if the country in the future will follow those lines, that when we call out our volunteer army it will be a worthy supplement to the volunteers whom we call regulars.

I am very much gratified that the spirit of the Army and Navy has turned to the assimilation of the engineering talent of the country. Von Moltke has well said that war is the only science that lays under tribute all other sciences; and, in this country, where we have such striking illustrations of the resourcefulness and ingenuity of the Americans, we believe the American soldier, who is first of all an American citizen, can and will, in the twentieth century, place himself on as high a level, as he has in the nineteenth century. To this end, of all things the most important in my mind is the question of electrical power and communication, in connection with military movements. The bringing together of the great forces of nature to be utilized for the building up of the country is a great thing, but to us in the Army and Navy, we feel that it is much more to our mind to be able to bring these same forces together to save the nation. I am sure we have with us to-day many men who have done work, as I am told Mr. Haskins did, which gave the country a feeling of satisfaction when the phantom fleet of Cervera was seen hovering off so many shores.

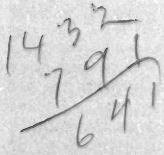
I am thankful, gentlemen, for your courtesy, and I feel that the Army and Navy owe a vote of thanks to your society for bringing forward this question, which is an important one—the use of electricity by the Army and Navy of the United States.

MR. CALVIN W. RICE:—(Chairman of the Committee on Papers and Meetings) Speaking for the Committee, I want to say we owe our gratitude to the officers of the Army and Navy who have come here to-night and given such an interesting meeting. The members who have been moving about the hall have heard a great many speak of what a profitable meeting this has been, and in the name of the INSTITUTE, I thank the gentlemen of the Army and Navy for their interest and coming here to-night.

MR. GEO. T. HANCHETT:—Referring to wireless telegraphy, I am going to venture a few remarks, in the hope that though they may be of lesser value, they will elicit from the experts we are fortunate to have with us, some valuable suggestions. I have not followed the literature of wireless telegraphy as thoroughly as I should, and I have nowhere read of any investigations or discussion as to why a coherer coheres. It has been generally accepted as a fact that it does cohere, and in the absence of in-

vestigations of this character, it seems to me that we have been searching somewhat blindly for a coherer that works. I am going to speak of some investigations that I conducted. I will illustrate on the blackboard. I took a slip of glass and cemented to it by means of shellac, two fine wires, so that the gap between them could be focused under the objective of a microscope. I placed between these points light powders of different kinds and observed the action when one side was connected to a mast of wire and the other to the earth, the entire system being influenced by the sparks of a distant induction coil. The results were substantially these: The wires appeared. of course, very large and the dust particles appeared as heavy lumps. Upon the spark of the induction coil passing, there was at once a mechanical motion of the particles, which cohered. With the metals in some of my coherers with which I could not send a dash, I found that the particles cohered and then flew apart. I then substituted light powders, which were not necessarily conductors, scrapings of chalk, lycopodium and the like. I found that powders flew together, cohering and instantly decohering. The conclusion seems to be that the action is electrostatic attraction and repulsion. If these things are true, it affords some interesting speculation as to what is the proper thing to use for coherer work. In the first place the powder must be light to respond readily to the minute forces acting upon it. In the second place it must be conducting. Any powder that appears to have the least tendency to be an insulator, due to oxide on its surface, is self-decohering to a very annoying degree. Silver-plated aluminium particles suggest themselves as perhaps being valuable for such work. My own experience has been that the filings from an ordinary American three-cent piece, gave me much better results than the filings from many expensive metals, and I may say that I tried all that could be obtained without great difficulty. If any one has anything further on this subject, I should be very much pleased to get the information.

[Adjourned.]



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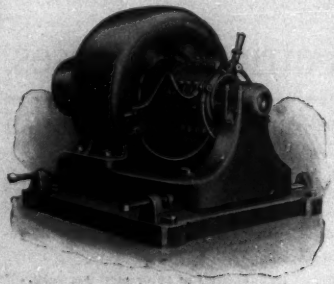

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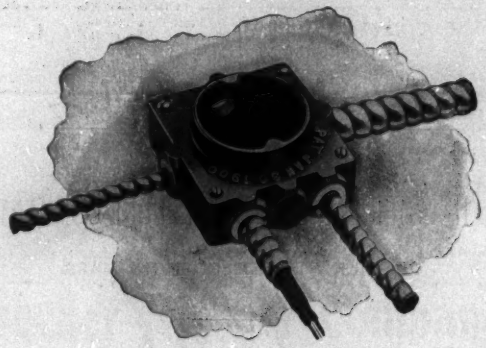

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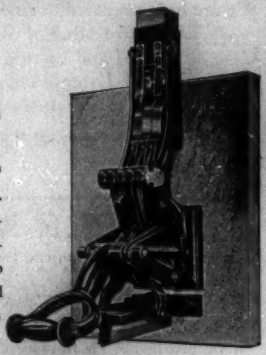

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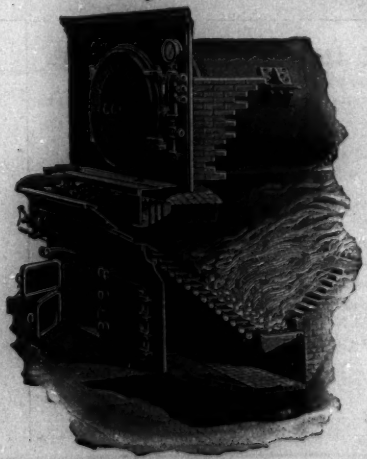

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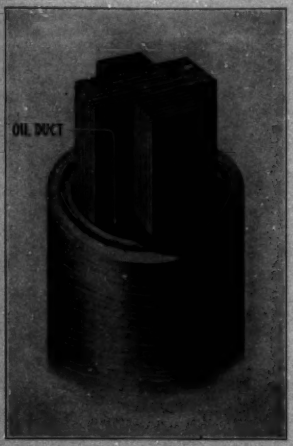

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